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EVALUATIONS OF AMMONIA APPLICATION TECHNIQUES

by

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INTRODUCTION

With the increasing costs of crop production in recent years the need has become evident for optimizing yields and minimizing input costs. Application costs of anhydrous ammonia in many cases represents a significant part of the variable production costs to produce a crop.

A possible way to reduce this cost is by applying anhydrous ammonia with a tillage operation. This has been done by combining anhydrous application with a V-blade, or other tillage operation where soil conditions permit.

Cold-Flo ammonia application technique was designed to assist ammonia application by a tillage implement such as a disc, field cultivator or chisel plow. There are two different types of Cold-Flo converters on the market. The single large converter is mounted near the center of the implement with lines leading to the shanks (Fig. 2). The other is the small individual shank converter which is mounted directly on the shank (Fig. 1). A possible problem with the large converter is uneven distribution of the ammonia between points of application. The liquid ammonia flows by gravity from the converter to the points of release. With the small converters, which are mounted on the shanks, ammonia is under pressure until right before the point of release. This may help improve the distribution between release points. The need for more work with this mode of ammonia application prompted establishment of these studies with these objectives:

1) To evaluate the yield effectiveness of Cold-Flo ammonia application along with other methods of ammonia application under dryland and irrigated conditions.

2) To compare distribution patterns of ammonia in the soil from different application methods.
3) To evaluate the effectiveness of methods of ammonia application on nutrient uptake.

LITERATURE REVIEW

When anhydrous ammonia is applied it must be retained in the soil for utilization by plants. An extensive review on retention patterns and factors affecting ammonia retention in the soil has been made by Swart (14). Retention of ammonia is the summation of all sorption and reaction mechanisms by organic and inorganic soil components (12).

Loss of N from the soil application of anhydrous ammonia can be classified as direct or indirect. Volatilization of ammonia into the atmosphere shortly after application is thought of as a "direct loss" (12). The ammonia has not undergone any transformation other than possible reaction with water. Such losses are generally the result of improper application or the inability of the soil to retain the applied ammonia, Parr and Engilbous (11). Improper application methods include the use of faulty application equipment and incomplete closure of the injection channel after application. Retention efficiency of soils may be increased by exposing a greater volume of soil to the applied ammonia.

Leaching and denitrification are indirect means of anhydrous loss. As long as the applied N remains as ammonium, leaching losses would not be expected. Ammonium is subject to nitrification by soil micro-organisms and as a result is leachable from the soil root zone as nitrite and nitrate anions. Denitrification takes place when soils become water-logged, oxygen is excluded, and anaerobic decomposition of organic matter takes place. Anaerobic micro-organisms have the ability

to obtain their oxygen from nitrites and nitrates with the accompanying release of nitrogen and nitrous gas. Soil pH, moisture level, partial pressure of the oxygen in the soil air and the amount of organic matter present all have an effect on denitrifaction (9).

Clay minerals can adsorb ammonia in a variety of ways. Cornet (3) suggested that if acid clays were reacted with ammonia, the ammonium ion would be attached to the clay surface. The ammonium form (NH_4^+) has a positive electrical charge and is attracted by the negative electrical charge of the clay mineral. While it is in this condition, it is also available for plant utilization or microbial nitrification. Barrer and MacLeod (1) found that ammonia is adsorbed by sodium and calcium montmorillinite clays. Other reactions of ammonia with clay minerals are coordination-type complexes with exchangeable bases and hydrogen bonding between the hydrogens of ammonia and oxygen of the clay mineral surface. Young and McNeal (17) suggested the possibility of a hydrogen bond between the nitrogen of NH_4^+ and the OH^- groups of the clay lattice.

Ammonia dissolves readily in water (McVicker _et al._, 9) and is adsorbed by organic matter and clay particles, making it possible for either wet or dry soils to retain ammonia. Soil moisture content has an affect on ammonia retention, distribution and the mechanism of retention. Ammonium hydroxide is formed when ammonia is applied to a wet soil.

Retention and distribution of anhydrous ammonia can also be affected by texture of the soil. McDowell and Smith (8) reported that

the loss of ammonia from sandy soils was greater than from air-dry silt loam or clay soils. As the texture of the soil becomes finer retention capacity increases.

Hydrogen ions in the soil solution or on clay particles will react with ammonia to form an ammonium ion (NH_4^+) which has a positive charge. Other cations held on the surface of a clay or organic matter particles may be replaced by these ammonium ions. Thus, the cation exchange capacity (CEC) of a soil is directly related to the ammonium retention capacity of the soil. Sohn and Peech (13) destroyed the organic matter of 12 different soils with peroxide. They found that 48.5% of the ammonia was retained in the organic matter. The amount of adsorption was directly related to the organic matter content.

The distribution of ammonia is affected by rate of application, depth of application and spacing between injection points. Blue and Eno (2) measured the lateral distribution of ammonia from the point of injection at a depth of approximately 12.7 cm. Using two rates of ammonia, 26.4 kg at 2.7% moisture and a 117 kg rate at 3% moisture. The 117 kg application rate had a retention zone diameter of approximately 10 cm while the 26.4 kg rate had a diameter of only 5 cm.

McDowell and Smith (8) applied anhydrous ammonia at 112 kg/ha rate to Putnam silt loam at various depths, spacing and soil moisture. Using 41 cm spacings on air dry soil, 4% of ammonia was lost at the 7.6 cm depth, whereas at the 15 cm depth only 2% of the ammonia was lost.

Cold-Flo Ammonia

Normally for agricultural use anhydrous ammonia is stored in pressurized tanks, keeping the ammonia primarily in a liquid state. Once the pressure is released the ammonia begins to vaporize. A new technique for reducing application pressure termed Cold-Flo ammonia involves releasing ammonia under pressure into a chamber. Pressure release allows approximately 15% of the ammonia to convert into vapor, (USS Cold-Flo manual, 1977. Agrichemical Division, Atlanta, Georgia). The boiling point of liquid ammonia is -33^{o}C. At this point for every gram of ammonia 327 calories (327 KcaL/kg) of latent heat is required to change it from liquid to vapor. The heat removed during vaporization is contained in the vapor as latent heat; that is the heat used to expand the liquid into vapor. Temperature of the vapor is the same as the liquid. If the depressurization takes place in a closed container such as a Cold-Flo converter, the heat of the container is immediately reduced until it is approximately the temperature of the liquid. Thus the ammonia as it flows through the Cold-Flo converter acts as its' own refrigerant. The liquid ammonia then flows through lines by gravity to the point of release. By applying the ammonia as a cold liquid, volatilization is slowed allowing time for the ammonia to be covered by soil. After the liquid ammonia is applied to the soil it then must be retained for utilization by plants.

Cold-Flo ammonia application technique was designed to allow shallow ammonia placement in the soil. Using this technique, ammonia could be applied with tillage operations resulting in a faster rate of application and possibly lower application costs by elimination of a

trip over the field with a conventional shank applicator. Little research has been conducted on the agronomic effectiveness and distribution pattern of Cold-Flo ammonia as compared to conventional ammonia application.

MATERIALS AND METHODS

Cold-Flo NH_3 application studies were conducted on wheat, corn and sorghum in the 1977 and 1978 crop years. Experiments were located in Shawnee, Riley, Stafford, Harper, Greeley and Franklin counties in Kansas. At each location a soil sample was taken and analyzed for N, P, K. organic matter and pH by the Soil Testing Laboratory at Kansas State University. Soil test data and general information of the soils are described in Table 1.

Wheat Studies

Wheat studies were conducted in Riley, Stafford and Harper counties in 1977. A randomized complete block design with four replications and eight treatments was utilized to compare method of nitrogen application, nitrogen source and time of N application (Table 2). Nitrogen rates were 0 and 84 kg/ha. Nitrogen carriers were anhydrous ammonia (82-0-0) and urea-ammonium nitrate solution (UAN, 28-0-0). Conventional application of anhydrous ammonia was carried out preplant in mid-August using a John Blue Model A-3700 Nitrolator on a 2.3 m wide shank applicator (Fig. 4). Shanks spaced 0.46 m apart placed the ammonia 12-15 cm deep. The Cold-Flo treatments were applied preplant with a 1.5 m wide tandem disc with a Cold-Flo converter mounted on

the disc. Ammonia was delivered to the soil surface directly beneath the spindle on the rear disc gang in an area where it was covered immediately by soil (Fig. 2) with points of ammonia release 0.38 m apart. The ammonia was incorporated as deep as 10 cm. The ammonia vapor in these studies was released to the atmosphere in order to eliminate uneven distribution caused by vapor injection at a single point. Rate of nitrogen application was adjusted to account for the lost vapor.

The UAN solution was applied through the use of a John Blue Model L-1094 positive displacement pump mounted on a Massey-Ferguson 135 tractor equipped with a ground speed dependent power-takeoff which eliminated variation in pump speed because of varying ground speeds. The UAN solution was applied through five nozzles mounted on a tool bar on 0.46 m centers and connected to the pump through a flow divider. The applicator was used to give two distribution patterns - dribble and broadcast. The dribble application of UAN solution was applied by removing the nozzles from the boom and allowing the solution to "dribble" from the nozzle openings. Broadcast applications consisted of leaving the nozzle tips in place and spraying the solution on the soil surface. All preplant treatments were incorporated immediately by discing. Topdressed applications (spring) of these same two UAN distribution patterns were not incorporated.

Plot dimensions were 3.0 m wide by 9.1 m long with a 9.1 m alley separating the replications. All three studies were seeded with Eagle cultivar hard red winter wheat at 67 kg/ha. Each study site was plowed before treatment application to turn under previous crop residue. At

Harper and Stafford county locations, a blanket application of starter fertilizer (18-46-0) at the rate of 67 kg/ha was applied to the study after treatment application but prior to planting. A light discing operation was used to incorporate the fertilizer and prepare the seedbed for planting. A discing/harrowing operation was used to prepare the seedbed at Riley county.

Plots were mechanically harvested using a modified Massey-Ferguson 35 combine. A strip 1.8 m wide was harvested from each plot and the grain weighed. After weights were recorded, a sample of grain was placed in a plastic bag for moisture determination and chemical analysis.

The 1978 wheat studies were located in Stafford and Riley counties. A randomized complete block design with four replications and thirteen treatments was used at the Riley county site to compare nitrogen rate and method of nitrogen application (Table 3). Nitrogen rates were 0, 34, 68, and 101 kg/ha. Methods of NH_3 application were conventional shank ammonia, field cultivator with ammonia, field cultivator with Cold-Flo ammonia and a preplant broadcast application of urea. Plot dimensions were 3.0 m wide and 9.1 m long with a 9.1 m wide alley between replications.

The field cultivator was designed to apply both conventional ammonia and Cold-Flo ammonia. Instead of a single large converter like the one used on the disc, individual converters were mounted on each of the four front shanks, 0.38 m apart (Fig. 1). A 38 liter tank fitted for ammonia was mounted on the field cultivator. A John Blue Model A-3700 Nitrolator was used to meter the ammonia through a manifold to the individual converters. Special delivery tubes were

mounted on the back of each field cultivator shank to hold the vapor line and liquid line in place and deliver the liquid and vaporized ammonia below the soil surface. The ammonia vapor was injected in front of the liquid ammonia point of release. A metal plate at the bottom of the liquid tube prevented soil from clogging the tube. Conventional ammonia was applied with the cultivator by removing the ammonia line from the top of the converters and connecting the delivery tube on the shanks by-passing the Cold-Flo units. The field cultivator was 1.5 m wide requiring two passes with the same treatment to completely cover each plot. Urea was applied as a conventional soil surface preplant treatment with a 2.4 m Barber metered flow dry fertilizer applicator (Fig. 4). The center 2.4 m of each plot received application of urea.

Cultivation practices for both studies in 1978 included a plowing operation to turn under previous crop residue and a discing operation prior to treatment application. After treatments were applied a harrowing operation was used to prepare the seedbed for planting.

Plots were seeded with Eagle cultivar variety of hard red winter wheat at 67 kg/ha rate in late October using a 1.8 m Ontario drill with 0.16 m drill spacing. Leaf tissue samples were taken in mid-April after initiation of spring growth but before jointing. Leaf analyses are reported in Table 3. These plots were mechanically harvested with a modified model "E" Gleaner combine. A strip 1.9 m wide was cut from each plot and the grain weighed. After weights were recorded a grain sample was placed in a plastic bag to be used for moisture determination and chemical analysis.

At the Stafford county site in 1978, a randomized complete block design with four replications was used. Methods of N application were conventional shank ammonia, disc with Cold-Flo ammonia, field cultivator with Cold-Flo ammonia and a broadcast preplant application of urea (Table 4). Rate of N application was 0, 34, 68 and 101 kg/ha.

Plots were seeded with Newton cultivar of hard red winter wheat in late October at 67 kg/ha. Plot dimensions were 3.0 m wide and 9.1 m long with a 9.1 m alley between replications. Leaf tissue samples were taken at boot state and prepared for chemical analysis. Plots were mechanically harvested as described for Riley county. Weights were recorded and samples saved for chemical analysis and moisture determination.

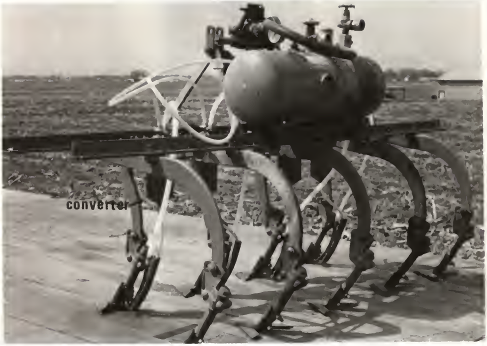
Corn Studies

Corn studies were conducted in the 1977 and 1978 crop years. A study located in Shawnee county at the Kaw Valley Irrigation Experimental Field in 1977 used a randomized complete block design with four replications and sixteen treatments designed to compare methods of ammonia application and nitrogen rates (Table 5). Methods of N application were conventional shank ammonia application, a disc with Cold-Flo ammonia, field cultivator with Cold-Flo ammonia, field cultivator with conventional ammonia and a broadcast application of urea. Nitrogen rates were 0, 84, 168 and 253 kg/ha. All treatments were applied preplant.

Cultural practices included a plowing operation to turn under previous crop resudue followed by a discing operation. After treatments were put on, a blanket application of fertilizer (18-46-0) was

Fig. 1. Field cultivator with small Cold-Flo converters mounted on the front shanks.

Fig. 2. Cold-Flo ammonia converter mounted near the center of a disc.


converter

applied at 112 kg/ha rate. A light discing and harrowing operation was used to incorporate the fertilizer and prepare the seedbed for planting. Weeds were controlled by a preplant application of herbicide at the rate of 3.36 kg A.I./ha of propachlor + 1.68 kg A.I./ha of Atrazine and one cultivation operation at the eight leaf stage. Irrigation was taken care of by field personnel.

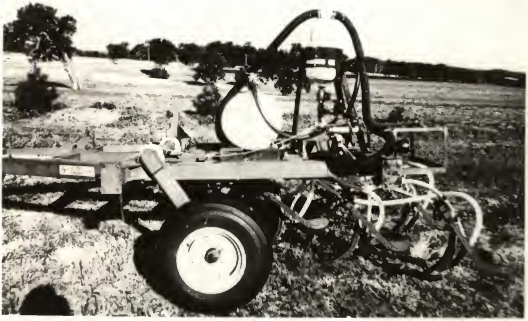
Plot dimensions were 3.0 m wide and 9.1 m long with a 9.1 m alley separating replications. Plots were planted with Pioneer 3183 corn on 0.80 m rows at 57,000 seeds/ha with four rows per plot. Leaf tissue samples were collected at the twelve leaf and a tasseling stages for chemical analysis.

In 1978, corn studies were conducted in Stafford and Greeley counties. At the Stafford county study, a randomized complete block design was used to compare method of ammonia application and nitrogen rate. Methods of ammonia application were conventional shank ammonia, field cultivator with Cold-Flo ammonia, chisel plow with Cold-Flo ammonia and chisel plow with conventional ammonia (Table 6). Nitrogen rates were 0, 84, 168 and 253 kg N/ha.

The chisel plow was 2.1 m wide. A large single Cold-Flo unit was mounted on the chisel approximately 0.9 m above the frame to provide enough head pressure so that the gravity flow ammonia would be evenly distributed between the seven shanks, 0.3 m apart (Fig. 3). Special delivery tubes for the liquid and vapor were mounted on the back of each shank to deliver the ammonia below the soil surface. Ammonia vapor was injected immediately behind the liquid release points. Nitrogen rates were 0, 84, 168 and 253 kg N/ha.

Fig. 3. A chisel plow equipped to apply either Cold-Flo ammonia or conventional "hot" ammonia.

Fig. 4. Combination dry fertilizer applicator, anhydrous ammonia shank applicator and UAN solution applicator mounted on a Massey Ferguson 135 tractor.



Cultural practices included a discing operation to turn under previous crop residues. After treatments were applied, a blanket application of fertilizer (18-46-0) was applied at 112 kg/ha rate. A discing operation was used to incorporate the fertilizer and to prepare the seedbed for planting. A preplant application of herbicide at the rate of 2.24 kg A.I./ha of Alachlor + 1.68 kg A.I./ha of Atrazine and a cultivation operation were used to control weeds. Irrigation was taken care of by the field personnel.

Plot dimensions were 3.0 m wide and 7.6 m long with a 6.1 m alley between the three replications. Corn was planted in 0.8 m rows with Dekalb XL72AA hybrid corn in late April by a planting rate of 57,000 seeds/ha with four rows per plot. Leaf tissue samples were collected at the eight leaf stage and at tasseling for chemical analysis.

One of the two center rows in each plot was hand harvested and mechanically shelled. After plot weights were recorded a sample was retained in a plastic bag for moisture determination.

The study in Greeley county was identical to the Stafford county study (Table 7). Plot dimensions were 3.0 m wide and 9.1 m long with a 9.1 m alley between the three replications.

Cultural practices included a plowing operation to turn under previous crop residue. A blanket application of triple superphosphate (0-46-0) at 50 kg/ha rate was applied to the study area and incorporated with a discing operation. After treatments were applied a light discing/harrowing operation was used to prepare the seedbed for planting. A post-emergence application of atrazine herbicide was used to control weeds and a bedding operation was done at the eight leaf stage for flood irrigation.

Corn was planted in 0.8 m rows with ACCO 8801 hybrid corn in late April at a planting rate of 57,000 seeds/ha. Plots were hand harvested and shelled on location. Plot yields were recorded and a sample retained from each plot for moisture determination.

Grain Sorghum

Grain sorghum studies in 1978 were initiated in Riley and Franklin counties. The Riley county site was later abandoned due to a severe infestation of chinch bugs. Both studies were rendomized complete block designs, with three replications comparing nitrogen rates and methods of ammonia application. Nitrogen rates were 0, 45, 90 and 135 kg/ha. Methods of ammonia application were conventional shank ammonia, field cultivator with ammonia; field cultivator with Cold-Flo ammonia, chisel plow with Cold-Flo ammonia and chisel plow with ammonia (Table 8). Leaf tissue samples were collected from flag leaves at heading for chemical analysis.

Plot dimensions were 3.0 m wide and 9.1 m long with a 9.1 m alley between replications. Plots were mechanically harvested with a Massey-Ferguson 35 combine. Yields were weighed in the field and samples were saved for moisture determination.

Cultural practices included a plowing operation in the fall to turn under previous crop residues. A discing operation was done prior to treatment application and a herbicide treatment of 2.24 kg A.I./ha of propachlor + 1.45 kg A.I./ha of Atrazine was used to control weeds during the growing season. A light discing/harrowing operation was used after treatments were applied to prepare the seedbed for planting.

Soil Sampling

Soil profile sampling was initiated in 1978 in an attempt to evaluate ammonia distribution patterns in the soil from the different methods of application. The Riley county sorghum study which was later abandoned was a major sampling site. Four methods of ammonia application were sampled; conventional shank ammonia, field cultivator with ammonia, field cultivator with Cold-Flo ammonia and chisel plow with ammonia. The nitrogen rate sampled was 135 kg/ha. All samples were collected from the second replication to minimize possible soil variation affecting the ammonia application. Samples were taken 10 days after treatment application.

The area sampled was 4.6 m from the end of the plot. Plots were sampled to a depth of 0.3 m, each sample being divided into 7.6 cm sections. Samples were collected every 2.5 cm for 1.5 m across the width of the plot. Samples were taken perpendicular to the line of travel of the applicator. Method of application determined area sampled. With the shank and chisel plow application methods only one pass was made with the applicator so the center 1.5 m of the plot was sampled. Two passes were required by the field cultivator with and without Cold-Flo ammonia. Facing the front of the plot, samples collected from these two methods of application were 1.5 m left of the center line of the plot.

A soil sampling apparatus (built by Dale Leikam, Kansas State University, Agronomy Department) for sampling profiles (Fig. 5) was used. Fifteen, 2.5 cm square steel tubes 0.61 m long were welded together in alternate rows. Soil probes were mounted on 1.9 cm square

tubing which fit snugly into the 2.5 cm square tubing. This frame acted as a guide minimizing error in collection of a perpendicular soil core. Samples were placed in soil sample bags and immediately dried and ground. They were then placed in glass jars and stored for later analysis for nitrate and ammonia.

Laboratory Analyses

Soils. Soil samples were analyzed for pH, P, K, organic matter and NH_4^+-N and NO_3^--N. Analyses for pH, P, and K were carried out by procedures used in the North Central Region (10). Organic matter was determined by a modified Walkley-Black procedure in which the samples were analyzed colorimetrically as outlined by Grahm (4). The above analyses are routine procedures in the Soil Testing Lab at Kansas State University and analyses carried out by the lab. Ammonium was assayed colorimetrically on a dual channel Technicon Auto-Analyzer (15) using industrial method 334-74W/B in which an emerald-green color is formed by the reaction of ammonia, sodium salicylate, sodium nitroprusside and sodium hypochlorite in an alkaline medium buffered at a pH of 12.8-13.0. The product of this reaction was measured with a spectrophotometer at a wavelength of 660 nm. Nitrate was assayed colorimetrically on the same extract using industrial method 487-77A (16) in which nitrate is reduced to nitrite by a copper-cadmium reductor column. The nitrite ion then reacts with sulfanalimide under acidic conditions to form a diazo compound. This compound then couples with N-1-naphthylethylenediamine dehydrochloride to form a reddish-purple azo dye which was measured at a wavelength of 520 nm.

Fig. 5. Soil sampler used in taking soil profile samples.

Plant Tissue. The dried samples were ground with a Wiley mill to pass through a 1 mm stainless steel screen. Approximately 7 g of the ground samples were stored in sealed plastic vials.

All samples were redried for 24 hours at 65 C prior to actual analysis. Nitrogen, phosphorus and potassium analysis followed a sulfuric acid digest (Linder and Harley, 7). A 0.25 g sample was weighed into a digestion tube and a 2 ml aliquot of sulfuric acid (concentrated) was added. The samples were placed under a hood in an aluminum digestion block and 1 ml of 30% H_2O_2 added. The samples were heated to a temperature of 375 C until the fumes condensed about half-way up the digestion tube. The samples were heated approximately 45 minutes. The samples were then cooled for 10 minutes and an additional 1 ml of 30% H_2O_2 was added and the samples reheated. This procedure was repeated until the digest solution remained clear. The digestion tubes were then removed from the heat, diluted to 50 ml with distilled deionized water and stored in polyethylene bottles. These solutions were then used for N, P, and K analysis.

Nitrogen was determined colorimetrically on a spectrophotometer at 660 nm. A 1 ml aliquot of the digested plant material was diluted to 10 ml with distilled deionized water. A half ml (0.5) of this solution was then diluted to 6 ml with distilled deionized water and mixed well.

A solution of sodium dichloroisocyanurate and 0.6 N sodium hydroxide was prepared by dissolving 24 g of reagent grade sodium hydroxide in 900 ml of distilled deionized water, cooling and adding 5 g of sodium dichloroisocyanurate. This solution, solution A, was

diluted to 1 liter. Another solution, solution B, was prepared by dissolving 85 g of sodium salicylate in 600 ml of distilled deionized water and adding 0.3 g of sodium nitroprusside and taking to a final volume of 1 liter.

A 2 ml aliquot of solution A was added to the diluted sample and then 2 ml of solution B added. Color was allowed to develop for 2 hours and then readings were taken on a spectrophotometer at 660 nm. A set of standards containing 0, 50, 100, 150, 200 and 250 ppm N as ammonium were prepared from a 1000 ppm stock solution of N as ammonium sulfate. Color on the standards was developed by the same procedure as the samples and a standard curve was determined. The nitrogen concentration in the samples was determined from this curve.

Phosphorus was determined in the digest using an ammonium molybdate-ammonium vanadate solution. The solution was prepared by dissolving 162 g of ammonium molybdate in 2 liters of distilled deionized water. Nine g of ammonium vanadate was dissolved in 2 liters of boiling distilled deionized water, cooled and mixed with the ammonium molybdate solution. This solution was then mixed with 675 ml of nitric acid and diluted to 18 liters.

Using a 1:10 Re-Pipet, a 1 ml aliquot of the sulfuric digest was added to 5 ml of the vanadomolybdate solution. The color was allowed to develop for 30 minutes and read on a spectrophotometer at 390 nm. A standard curve was prepared by preparing standards of 6, 12, 24, 36 and 48 ppm phosphorus from a stock solution containing 660 ppm phosphorus from potassium dihydrogen phosphate and 4 ml of concentrated sulfuric acid. A 1 ml aliquot of these standards was added to 5 ml

of the vanadomolybdate solution. The color was allowed to develop for 30 minutes and read on the spectrophotometer. The final standards had concentrations of 1, 2, 4, 6 and 8 ppm phosphorus. The formula, C = K (OD) was used to determine phosphorus concentrations in the samples by determining an average K value and reading absorbance.

In 1978, this colorimetric procedure was adapted for a Technicon Auto-Analyzer (same procedure as soils) for nitrogen and phosphorus determination in plant tissue.

Potassium was determined by diluting the sulfuric acid digest 1:10 with distilled deionized water and running by flame spectrophotometry. A standard curve was determined by using standard solutions of 0, 5, 10, 20 and 30 ppm potassium from a stock solution of potassium chloride.

A second digestion of the dried ground plant material was accomplished by using 7.5 ml of a 1:1 mixture of nitric acid and perchloric acid to digest 0.5 g of the plant material in digestion tubes heated in aluminum blocks. The digested samples were then diluted to 25 ml using 0.1 N hydrochloric acid.

These samples were then analyzed for calcium and magnesium by atomic absorption spectrophotometry. A solution of 1% lanthanum was added as an internal standard for the calcium analysis.

Grain Analysis. Grain samples were ground through a Udy cyclone sample mill and approximately 10 grams were stored in plastic vials and saved for analysis. Nitrogen in the grain was determined by the same procedure outlined for plant tissue.

Statistical Analysis Procedures. The data collected in 1977 was analyzed by the General Analysis of Variance (GANOVA) system. In 1978, data was analyzed by the Statistical Analysis System (SAS) developed at North Carolina State University. Both systems were available as a computing service at the computing center of Kansas State University.

The figures in the results and discussion section of this thesis were produced using a Calcomp plotter and plotting program developed by Kemp *et al*. (5).

RESULTS AND DISCUSSION

The discussion is broken into sections on the wheat, corn and grain sorghum studies and soil sampling for NH_3 retention pattern. Nitrogen rate, time of application, method of application and nitrogen source are examined as to their effect on wheat yields, protein and nutrient uptake in the wheat section. In the corn and grain sorghum studies, method of application and rate of application are examined as to their effects on yields and nutrient uptake. In the last section, distribution of ammonia and size of the retention zones are evaluated.

Wheat Studies

Yield and protein data from three locations of Cold-Flo ammonia evaluation in 1977 are shown in Table 2. Wheat yields were not significantly (5% level) affected by N application method, nitrogen rate and time of N application. There were no significant yield differences between nitrogen carriers, method of application and time of application at the three locations. Appendix Figure 1 compares individual treatment effects on yields.

TABLE 1. GENERAL SOIL DESCRIPTION AND SOIL TYPE

Crop Year	Location	County	Soil Type	Soil Depth (cm)	Organic Matter (%)	pH	ppm P	ppm K	ppm N
Wheat, 1977	Ashland Agronomy Farm	Riley	Muir Sil Pachic Haplustoll	0-15	1.4	6.0	28.0	320	19.3
Wheat, 1977	Sandy Land Exper. Farm	Stafford	Naron FSL Udis Argiustoll	0-15	0.7	6.3	20.0	112	7.4
Wheat, 1977	Dennis Baker Farm	Harper	Bethany Sil Pachic Paleustoll	0-15	1.3	6.0	5.0	340	14.0
Corn, 1977	Kaw Valley Exper. Field	Shawnee	Eudora Sil Fluventic Hapludolls	0-15	0.8	6.2	36	198	7.2
Wheat, 1978	Ashland Agronomy Farm	Riley	Muir Sil Pachic Haplustoll	0-15	1.5	6.2	30.0	330	13.5
Wheat, 1978	Sandy Land Exper. Farm	Stafford	Naron FSL Udic Argiustoll	0-15	0.8	6.3	23.0	107	8.0
Corn, 1978	Sandy Land Exper. Farm	Stafford	Farnum FSL Udic Argiustoll	0-15	0.9	6.4	22.0	115	10.2
Corn, 1978	Tribune Exper. Field	Greeley	Ulysses Sil Aridic Haplustolls	0-15	1.4	7.8	35	500+	12.1
Sorghum, 1978	East Central Exper. Field	Franklin	Woodson Sil Abruptic Argiaquolls	0-15	2.3	6.3	42.0	383	14.0

TABLE 2. EFFECTS OF NITROGEN APPLICATION METHODS ON WINTER WHEAT YIELD AND PROTEIN, 1977

				Stafford Co.			Riley Co.			Harper Co.		
		Method	Time	Yield		Protein	Yield		Protein	Yield		Protein
kg/ha	Nitrogen Carrier	Nitrogen Application	Nitrogen Application	bu/A	kg/ha	%	bu/A	kg/ha	%	bu/A	kg/ha	%
0	---	---	---	36.1	2428	10.4	45.1	3033	10.8	35.3	2374	10.0
84	UAN	B'cast	Preplant	37.0	2488	12.1	41.4	2784	12.0	42.7	2872	12.1
84	UAN	Dribble	Preplant	37.7	2535	12.7	47.1	3167	11.6	38.2	2569	11.5
84	UAN	Shanked	Preplant	36.1	2428	12.8	41.1	2764	12.6	33.8	2273	13.0
84	NH_3	Cold-Flo	Preplant	38.7	2603	11.3	48.6	3268	10.3	39.9	2683	11.6
84	NH_3	Shanked	Preplant	37.9	2549	13.4	49.5	3329	11.8	43.0	2892	12.3
84	UAN	B'cast	Topdressed	35.6	2394	12.3	47.2	3174	13.1	40.7	2737	12.0
84	UAN	Dribble	Topdressed	36.4	2448	13.9	41.4	2784	14.3	36.1	2428	13.2
$LSD_{.05}$ Treatment				NS	NS	0.8	NS	NS	1.9	NS	NS	1.2

Appendix Figure 2 indicates the grain protein at each location for 1977. All three locations, the UAN dribble or broadcast topdressed treatments produced a significant increase in protein over the control plots. At the Stafford county location, UAN dribble topdress was significantly higher than all other treatments except preplant shanked ammonia. The UAN dribble topdressing at the Riley county location produced a significant increase in protein over the other treatments with the exceptions of UAN shanked preplant and the broadcast UAN topdressing. At the Harper county location UAN dribble topdressing produced a significant increase in protein over UAN dribble preplant broadcast topdressing and Cold-Flo ammonia preplant treatments. At the Riley county site, Cold-Flo ammonia had no significant effect on protein compared to the control.

In 1978 at the Riley and Stafford county locations, methods of ammonia application had no significant effects on yields (Table 3 and 4). Appendix Figures 3-6 include individual treatment effects on yield and protein from these two locations. Yields were not significantly increased when nitrogen rates were increased from 34 kg/ha to 101 kg/ha at Riley county. The Stafford county produced unexpected results with the lower nitrogen rate (34 kg/ha) producing a significantly higher yield than the 101 kg/ha rate. This may have been due to the increased lodging at the higher nitrogen rate and subsequently reduced yields. Grain protein was not significantly affected by method of N application and nitrogen rate at either location in 1978.

Tissue samples were not collected in 1977, but in 1978 wheat tissue samples were collected at the Riley and Stafford county sites and results

are reported in Tables 3 and 4. At the Riley county location method of ammonia application had no significant effect on nutrient uptake. Tissue nitrogen was significantly affected by method of ammonia application at the Stafford county location with shank ammonia being significantly higher than disc with Cold-Flo ammonia and broadcast urea. Field cultivator with Cold-Flo ammonia also produced significantly higher tissue nitrogen concentrations than the disc with Cold-Flo ammonia. Phosphorus concentration in the tissue was not significantly affected by N application at either location.

Increasing N rates from 34 kg/ha to 101 kg/ha had no significant effect on tissue levels of nitrogen and phosphorus at the Riley county site. At the Stafford county location, the 101 kg/ha rate produced significantly higher concentrations of tissue N than the 34 kg/ha rate. Phosphorus levels were not significantly effected by N rate.

Yield results indicate no significant differences between methods of ammonia application but results are inconclusive because of a lack of a nitrogen response at any of the locations. Also, method of ammonia application had no consistent significant effect on nutrient uptake.

Corn Studies

At the Shawnee county location in 1977 an excellent response to N was found, but method of nitrogen application had no significant effect on yield (Table 5). Appendix Figure 7 compares individual treatment effects according to nitrogen rates on yields. The 84 kg/ha and 253 kg/ha nitrogen rates produced significantly higher yields than the 168 kg/ha rate and cannot be explained.

TABLE 3. EFFECTS OF AMMONIA APPLICATION METHODS ON WINTER WHEAT, RILEY CO., 1978

Nitrogen rate (kg/ha)	Application method	Nitrogen carrier	Tissue (4/15)		Grain	Yield	
			%N	%P	%Protein	bu/A	kg/ha
0	------	------	1.57	.31	10.5	37.7	2535
34	Shank	NH_3	1.82	.31	10.2	40.8	2744
68			1.85	.30	10.7	38.6	2596
101			1.85	.31	10.3	39.9	2683
34	Field Cultivator	NH_3	1.78	.32	10.2	39.1	2629
68			1.75	.30	10.9	36.6	2461
101			1.99	.31	10.5	38.0	2556
34	Field Cultivator + Cold-Flo	NH_3	2.00	.31	10.9	39.6	2663
68			1.83	.30	10.8	39.5	2656
101			1.81	.30	10.3	43.6	2932
34	Broadcast	Urea	1.69	.31	10.5	39.0	2623
68			1.86	.31	10.7	39.9	2683
101			2.00	.30	10.7	41.6	2798
$LSD_{.05}$ Treatment			.21	NS	NS	NS	NS

TABLE 3. (Cont'd.) EFFECTS OF AMMONIA APPLICATION METHODS ON WINTER WHEAT, RILEY CO., 1978 (MEAN VALUES)

Nitrogen rate (kg/ha)	Nitrogen application method	Tissue (4/15) %N	Tissue (4/15) %P	Grain %Protein	Yield bu/A	Yield kg/ha
	Shank	1.84	.308	10.4	39.8	2677
	Field Cultivator	1.84	.309	10.5	37.9	2549
	Field Cultivator + Cold-Flo	1.88	.302	10.6	40.9	2751
	Broadcast Urea	1.85	.306	10.6	40.2	2703
	$LSD_{.05}$ Method	NS	NS	NS	NS	NS
34		1.82	.31	10.5	39.6	2663
68		1.83	.30	10.8	38.6	2596
101		1.91	.30	10.5	40.8	2744
$LSD_{.05}$ Rate		NS	NS	NS	NS	NS

TABLE 4. EFFECTS OF AMMONIA APPLICATION METHODS ON WINTER WHEAT, STAFFORD CO., 1978

Nitrogen rate (kg/ha)	Application method	Nitrogen carrier	Tissue (4/16)		Grain	Yield	
			%N	%P	%Protein	bu/A	kg/ha
0	------	------	2.25	.26	9.2	39.7	2670
34	Shank	NH_3	2.43	.23	9.2	42.2	2838
68			2.95	.25	9.6	38.7	2603
101			2.96	.25	10.5	37.3	2508
34	Disc + Cold-Flo	NH_3	2.30	.27	8.5	42.2	2838
68			2.20	.25	9.1	39.6	2663
101			2.47	.25	9.6	39.1	2629
34	Field Cultivator		2.48	.24	9.4	39.4	2650
68			2.58	.25	11.3	41.2	2771
101			2.74	.23	8.8	39.6	2663
34	Broadcast	Urea	2.25	.24	8.5	41.2	2771
68			2.33	.24	9.3	38.3	2576
101			2.68	.22	10.3	35.3	2374
$LSD_{.05}$ Treatment			.39	NS	NS	NS	NS

TABLE 4. (Cont'd.) EFFECTS OF AMMONIA APPLICATION METHODS ON WINTER WHEAT, STAFFORD CO., 1978 (MEAN VALUES)

Nitrogen rate (kg/ha)	Nitrogen application method	Tissue (4/16)		Grain	Yield	
		%N	%P	%Protein	bu/A	kg/ha
	Shank	2.78	.244	9.8	39.4	2650
	Disc + Cold-Flo	2.32	.257	9.1	40.3	2710
	Field Cultivator + Cold-Flo	2.59	.239	9.9	40.0	2690
	Broadcast Urea	2.42	.235	9.3	38.3	2576
	$LSD_{.05}$ Method	0.23	NS	NS	NS	NS
34		2.36	.246	8.9	41.2	2771
68		2.51	.248	9.8	39.5	2656
101		2.71	.238	9.8	37.8	2542
$LSD_{.05}$ Rate		0.20	NS	NS	2.6	175

Nitrogen concentrations in corn leaf tissue were significantly affected by methods of ammonia application at Shawnee county at the first sampling date, Table 5. Conventional shank ammonia increased tissue levels of nitrogen significantly over other methods of ammonia applications at the first sampling date. Methods of ammonia application had no significant effect on tissue concentrations of phosphorus at the first sampling date. At the second sampling date, there was essentially no difference between methods of ammonia applications in terms of tissue nitrogen and phosphorus concentrations.

Methods of ammonia application had variable effects on tissue potassium concentrations with shank ammonia being significantly lower than the other methods except broadcast urea at first sampling. This could be due to higher N concentrations and possible ammonium-potassium absorption competition. This effect on potassium concentration was also noticed at the second sampling date. Yields for the shank ammonia application method were generally higher but not significantly higher than other methods, suggesting better uptake of nitrogen with this method. Field cultivator with Cold-Flo ammonia produced significantly higher calcium tissue concentrations than the shank ammonia method at the first sampling date. There was no difference at the second sampling date. Disc with Cold-Flo ammonia produced a significant increase in tissue magnesium concentration compared to shank ammonia and broadcast urea at the first sampling date. There was no difference at the second sampling date.

Nitrogen rate had no significant effect on tissue levels of nitrogen, phosphorus and potassium at either sampling date in 1977 at Shawnee county at the 5% probability level. Tissue concentrations of

calcium were significantly affected, the 253 kg/ha rate being significantly higher than the 84 and 168 kg/ha rates. At the second sampling date the 84 and 253 kg/ha rates of nitrogen significantly increased calcium concentrations in the leaf tissue over the 168 kg/ha rate. Magnesium concentrations in leaf tissue were not significantly affected at the first sampling date. At the second sampling date, the 84 kg/ha rate of nitrogen produced significantly higher concentrations of magnesium in the tissue than did the 168 and 253 kg/ha rates.

This would agree with the findings of Lamond (6) when he reported that ammonium-N consistently and often significantly resulted in lower concentrations of K, Ca and Mg in forages compared to nitrate-N. Although no nitrate-N was used in this study, competition between NH_4 and Mg uptake could significantly decrease Mg concentrations as N rates increased from 84 kg N/ha to 253 kg N/ha.

Results in this study were quite variable. This may have been due in part to the extremely sandy soil, which has little buffering capacity and the abnormally high temperatures during the growing period. Severe stripping of the leaves was prominent throughout most of the growing season up to tasseling. These symptoms are suggestive of Mg deficiency and relatively low Mg levels were found in plant tissue. Normal tissue levels of Mg are around .2-.3% in corn.

In 1978 at the Stafford county location, method of ammonia application had no significant effect on corn yield (Table 6). Appendix Figure 8 compares individual treatments according to nitrogen rates. Nitrogen rates averaged across methods indicate that the 168 kg/ha rate yielded slightly higher than the 253 kg/ha rate and significantly higher than the 84 kg/ha rate.

TABLE 5. EFFECTS OF AMMONIA APPLICATION METHODS ON CORN YIELDS, SHAWNEE CO., 1977

N-Rate kg/ha	Application Methods	N Source	Tissue Composition: 12 Leaf Stage %N	12 Leaf Stage %P	12 Leaf Stage %K	12 Leaf Stage %C	12 Leaf Stage %Mg	Tassel %N	Tassel %P	Tassel %K	Tassel %Ca	Tassel %Mg	Yield bu/a	Yield kg/ha
0	----		2.00	.43	2.92	.27	.12	1.08	.20	2.11	.43	.14	35.1	2207
84	Shank	NH_3	2.50	.37	2.85	.28	.12	1.69	.20	2.18	.45	.14	78.8	4954
168	Shank	NH_3	3.25	.40	2.70	.27	.11	1.72	.19	2.36	.40	.10	91.3	5740
253	Shank	NH_3	3.50	.36	2.47	.28	.11	2.20	.22	2.17	.47	.09	121.6	7645
84	Disc Cold-Flo	NH_3	2.75	.40	2.75	.27	.12	1.72	.20	2.24	.49	.12	74.7	4697
168	Disc Cold-Flo	NH_3	2.25	.39	2.80	.32	.13	1.80	.22	2.19	.45	.12	73.4	4615
253	Disc Cold-Flo	NH_3	3.00	.40	2.85	.33	.13	1.82	.21	2.14	.46	.11	86.6	5445
84	Field Cultivator + Cold-Flo	NH_3	2.50	.35	2.85	.29	.12	1.93	.22	2.14	.48	.11	84.2	5294
168	Field Cultivator + Cold-Flo	NH_3	2.50	.40	2.82	.35	.12	1.67	.21	2.09	.43	.13	42.0	2641
253	Field Cultivator + Cold-Flo	NH_3	2.75	.38	2.70	.32	.13	1.60	.19	2.17	.45	.10	70.1	4407
84	Field Cultivator	NH_3	2.00	.38	2.90	.29	.13	1.72	.21	2.08	.46	.15	75.5	4747
163	Field Cultivator	NH_3	2.25	.39	2.80	.32	.13	1.33	.20	2.08	.45	.10	33.3	2094
253	Field Cultivator	NH_3	2.25	.39	2.77	.36	.14	1.68	.22	2.08	.47	.12	65.8	4137
84	Broadcast	UREA	2.00	.40	2.72	.28	.12	1.63	.23	2.09	.49	.16	61.4	3860
168	Broadcast	UREA	2.00	.37	2.75	.30	.13	1.42	.19	2.05	.46	.11	43.3	2722
253	Broadcast	UREA	2.50	.34	2.75	.32	.12	1.85	.21	2.11	.46	.11	84.5	5313
$LD_{.05}$ Treatment			0.7	NS	.16	.06	NS	NS	NS	.15	NS	NS	35.7	2245

TABLE 5. (Cont'd.) EFFECTS OF AMMONIA APPLICATION METHODS ON CORN YIELDS, SHAWNEE CO., 1977 (MEAN VALUES)

Mean Values	Tissue Composition											
	12 Leaf Stage					Tasseling					Yield	
	%N	%P	%K	%Ca	%Mg	%N	%P	%K	%Ca	%Mg	bu/A	kg/ha
Field Cultivator Cold-Flo NH_3	2.58	.38	2.79	.32	.13	1.87	.20	2.23	.44	.11	65.4	4112
Shank	3.08	.38	2.67	.28	.12	1.58	.21	2.06	.46	.13	97.2	6111
Disc + Cold-Flo	2.16	.38	2.82	.32	.14	1.73	.21	2.13	.45	.11	78.2	3659
Field Cultivator	2.66	.40	2.80	.31	.13	1.78	.21	2.19	.46	.12	58.2	4917
Broadcast UREA	2.16	.37	2.74	.30	.12	1.63	.21	2.09	.47	.13	63.0	3961
$LSD_{.05}$ Method	.4	NS	.10	.03	.02	NS	NS	.08	NS	NS	NS	NS
Nitrogen Rate												
84	2.35	.38	2.82	.29	.12	1.74	.21	2.15	.47	.14	74.9	4709
168	2.45	.39	2.78	.31	.12	1.58	.20	2.15	.44	.11	56.6	3558
253	2.80	.37	2.71	.32	.13	1.83	.21	2.12	.46	.11	85.7	5388
$LSD_{.05}$ Rate	NS	NS	NS	.02	NS	NS	NS	NS	.02	.02	16.4	1031

Fig. 6. Visual effects of ammonia application methods on corn. Shank ammonia vs. disc with Cold-Flo ammonia (Shawnee Co., 1977).

Fig. 7. Visual effects of ammonia application methods on corn. Field cultivator with ammonia vs. field cultivator with Cold-Flo ammonia (Shawnee Co., 1977).


METHODS N
APPLICATION
225 N
DISC
SHANK
COLD FLO
SHAWNEE CO., KAN


METHODS N
APPLICATION
150 N
FIELD
CULT
FIELD
CULT
COLD FLO

TABLE 6. EFFECTS OF AMMONIA APPLICATION METHODS ON IRRIGATED CORN, STAFFORD CO., 1978

Nitrogen rate (kg/ha)	Application method	Nitrogen carrier	8-leaf stage, 5/15			Tassel, 7/10			Yield	
			%N	%P	%K	%N	%P	%K	bu/A	kg/ha
--	------	-----	2.68	.376	3.11	2.17	.256	1.92	117.5	7388
84	Shank	NH_3	3.16	.387	3.31	2.74	.251	1.73	149.7	9412
168			3.31	.414	3.19	2.95	.272	1.98	162.0	10185
253			3.73	.401	2.80	3.26	.283	1.88	158.2	9946
84	Field Cultivator	NH_3	2.79	.389	3.51	2.54	.256	1.82	130.7	8217
168			2.98	.415	3.22	2.90	.279	1.88	159.5	10028
253			2.98	.390	3.04	2.85	.266	1.83	138.0	8676
84	Field Cultivator + Cold Flo	NH_3	2.70	.389	3.17	2.60	.243	1.78	125.6	7897
168			3.00	.408	3.29	2.63	.255	1.66	145.6	9154
253			3.14	.381	3.14	2.83	.269	1.80	149.0	9368
84	Chisel Plow + Cold-Flo	NH_3	2.90	.445	3.57	2.50	.252	1.70	145.0	9117
168			3.04	.401	2.92	2.90	.269	1.79	165.2	10387
253			3.47	.396	2.87	2.90	.250	1.85	156.5	9840
84	Chisel plow	NH_3	2.80	.400	3.45	2.42	.248	1.83	138.8	8727
168			3.13	.383	2.85	2.95	.261	1.82	158.4	9959
253			3.72	.373	2.93	2.98	.259	1.91	152.4	9582
$LSD_{.05}$ Treatment			0.52	NS	NS	0.32	NS	NS	NS	NS

TABLE 6. (Cont'd.) EFFECTS OF AMMONIA APPLICATION METHODS ON IRRIGATED CORN, STAFFORD CO., 1978 (MEAN VALUES)

Nitrogen rate (kg/ha)	Nitrogen application method	8-leaf stage, 5/15			Tassel, 7/10			Yield	
		%N	%P	%K	%N	%P	%K	bu/A	kg/ha
	Shank NH_3	3.40	.400	3.10	2.98	.268	1.86	156.6	9846
	Field Cultivator NH_3	2.92	.398	3.26	2.76	.267	1.84	142.7	8972
	Field Cultivator + Cold-Flo NH_3	2.95	.393	3.20	2.69	.256	1.74	140.0	8802
	Chisel Plow + Cold-Flo NH_3	3.14	.414	3.12	2.76	.257	1.78	155.7	9789
	Chisel Plow NH_3	3.22	.385	3.08	2.78	.256	1.85	149.9	9425
	$LSD_{.05}$ Method	0.31	NS	NS	0.18	NS	NS	NS	NS
84		2.87	.402	3.40	2.56	.250	1.77	138.0	8676
168		3.09	.404	3.09	2.87	.267	1.83	158.0	9934
253		3.41	.388	2.96	2.96	.265	1.86	151.0	9494
$LSD_{.05}$ Rate		0.24	NS	NS	0.14	.014	NS	15.9	1000

TABLE 7. EFFECTS OF AMMONIA APPLICATION METHODS ON IRRIGATED CORN, GREELEY CO., 1978

Nitrogen rate (kg/ha)	Application method	Nitrogen carrier	Tissue			Yield	
			%N	%P	%K	bu/A	kg/ha
------	------	------	3.07	.354	3.69	106.7	6709
84	Shank	NH_3	3.56	.341	3.71	107.9	6784
168			3.70	.331	3.87	117.3	7375
253			3.86	.336	3.84	116.9	7350
84	Field Cultivator	NH_3	3.44	.296	3.75	98.8	6212
168			3.54	.322	3.82	114.2	7180
253			3.63	.310	3.82	125.2	7872
84	Field Cultivator + Cold-Flo	NH_3	3.44	.362	3.76	99.7	6268
168			3.54	.322	3.82	114.2	7180
253			3.72	.334	3.49	108.4	6815
84	Chisel Plow + Cold-Flo	NH_3	3.38	.395	3.58	104.3	6558
168			3.72	.329	3.91	113.8	7155
253			3.72	.328	3.75	133.5	8394
84	Chisel Plow	NH_3	3.59	.344	3.79	128.1	8054
168			3.72	.332	3.74	117.5	7388
253			3.74	.323	3.82	126.5	7953
$LSD_{.05}$ Treatment			.30	NS	NS	NS	NS

TABLE 7. (Cont'd.) EFFECTS OF AMMONIA APPLICATION METHODS ON IRRIGATED CORN, GREELEY CO., 1978 (MEAN VALUES)

Nitrogen rate (kg/ha)	Nitrogen application method	Tissue			Yield	
		%N	%P	%K	bu/A	kg/ha
	Shank NH_3	3.71	.336	3.81	114.0	7167
	Field Cultivator NH_3	3.63	.309	3.80	113.5	7136
	Field Cultivator + Cold-Flo NH_3	3.57	.339	3.69	107.5	6759
	Chisel Plow +	3.61	.351	3.75	117.2	7369
	Cold-Flo NH_3	3.68	.333	3.78	124.0	7796
	$LSD_{.05}$ Method	NS	NS	NS	NS	NS
84		3.48	.347	3.72	107.7	6771
168		3.70	.327	3.83	115.8	7281
253		3.73	.326	3.74	122.1	7677
$LSD_{.05}$ Rate		0.14	NS	NS	NS	NS

At Stafford county application of nitrogen increased tissue levels of N above the control plots. Nitrogen rates produced a significant effect on tissue concentrations of nitrogen at both sampling dates. At the first sampling date, the 253 kg/ha N rate produced significantly higher N concentrations than the 84 and 168 kg/ha N rates. The 168 and 253 kg/ha N rates at the second sampling date produced significantly higher concentrations than the 84 kg/ha N rate.

In 1978 at the Greeley county location, corn yields were not significantly affected by methods of ammonia application (Table 7). Application of nitrogen did increase yields over the control. Effects of nitrogen rates were non-significant at the 5% probability level. However, the 253 kg/ha N rate was significantly higher than the 84 kg/ha N rate at the 10% probability level. This location received hail damage early in the growing season which allowed corn smut to infest the corn and was detrimental to yield. Appendix Figure 9 compares individual treatment effects on yields.

Method of ammonia application had no significant effect on nitrogen, phosphorus and potassium concentration in the leaf tissue at Greeley county. Applications of nitrogen did increase tissue nitrogen concentrations above the control. Nitrogen rates produced a significant response in tissue nitrogen concentration with the 168 and 253 kg/ha N rate being significantly higher than the 84 kg/ha N rate.

Method of ammonia application had no significant affect on yields at any of the locations and no consistent significant affect on nutrient uptake.

Grain Sorghum Study

A grain sorghum study was carried out in 1978 in Franklin county to evaluate Cold-Flo ammonia application techniques for that crop. The results of that study are reported in Table 8.

Methods of ammonia application had no significant effect on yields. Appendix Figure 10 compares individual method of N application within nitrogen rates. Nitrogen rate had no significant affect on sorghum yields at this location. Results were quite variable due to the extremely dry weather during the growing period. A considerable amount of lodged stalks due to moisture stress induced stalk rot were noticed at harvest time. The combine could not pick up those stalks therefore their yields were lost. Visual observations could not pick out any consistent treatment effect on lodging.

Soil Profile Sampling

To determine ammonia distribution patterns in the soil, the abandoned sorghum study at Riley county (chinch bug damage) was the major profile sampling site. Treatments sampled were the field cultivator with ammonia, field cultivator with Cold-Flo ammonia, conventional shank ammonia and chisel plow with Cold-Flo ammonia. Only the 135 kg/ha nitrogen rate was sampled. Results of these samplings are presented in Appendix Figures 11-14. Only the top 15 cm of soil data values are reported. There was essentially no N from the different methods of ammonia application below this depth.

TABLE 8. EFFECTS OF AMMONIA APPLICATION METHODS ON DRYLAND GRAIN SORGHUM, FRANKLIN CO., 1978

Nitrogen rate (kg/ha)	Application method	Nitrogen carrier	Tissue			Yield	
			%N	%P	%K	bu/A	kg/ha
---	---	--	2.48	.26	1.36	48.5	3049
45	Shank	NH_3	2.71	.29	1.52	43.7	2748
90			2.68	.29	1.56	48.2	3030
135			2.71	.28	1.39	38.1	2395
45	Field Cultivator	NH_3	2.72	.28	1.39	43.9	2760
90			2.50	.27	1.53	43.0	2704
135			2.70	.29	1.49	63.2	3974
45	Field Cultivator + Cold-Flo	NH_3	2.74	.29	1.51	35.4	2226
90			2.50	.27	1.61	36.4	2289
135			2.80	.30	1.56	48.5	3049
45	Chisel Plow + Cold-Flo	NH_3	2.77	.30	1.45	48.3	3037
90			2.75	.30	1.49	38.9	2446
135			2.59	.27	1.50	35.0	2201
45	Chisel Plow	NH_3	2.79	.29	1.51	45.4	2854
90			2.63	.27	1.45	42.2	2653
135			2.84	.31	1.49	41.0	2578
$LSD_{.05}$ Treatment			NS	NS	NS	NS	NS

Fig. 8. Visual effects of ammonia application methods on winter wheat. Shank ammonia vs. disc with Cold-Flo ammonia (Stafford Co., 1977).

Fig. 9. Visual effects of ammonia application methods on grain sorghum. Shank ammonia vs. chisel plow with Cold-Flo ammonia (Franklin Co., 1978).


COLD FLO
75 NH_3
SHANK C FLO
ST JOHN KS


COLD FLO NH_3
120 LB N/A
SHK CHS&CF
FRANKLIN CO
AUG 1978

Distribution patterns from each implement were variable with the chisel plow Cold-Flo ammonia have the most variation. Only three ammonia injection points were sampled from the field cultivator with conventional ammonia. Four injection points were sampled from the field cultivator with Cold-Flo ammonia application. Depth of ammonia concentrations was variable between release points due to soil surface fluctuation in relationship to sampling. The ammonia retention zone of the field cultivator with conventional ammonia and field cultivator with Cold-Flo ammonia (non-pressurized ammonia) were compared. Width of the retention zones were approximately the same for both methods, about 15 cm. Thus the lateral movement of NH_3 was not affected by the Cold-Flo NH_3 technique suggesting that the final equilibrium chemistry is the same for NH_3 retention. Appendix Tables 1-4 contain the raw data values for each ammonia application. The values used in the graphs are the summation of ammonium-N and nitrate-N in each sample.

SUMMARY AND CONCLUSIONS

Cold-Flo ammonia did not significantly change yields of corn, sorghum and wheat when compared to other methods of ammonia application. Although Cold-Flo ammonia did perform as well as the other methods of ammonia application, there were no apparent agronomic advantages in using the Cold-Flo method. This may be due to the fact that even when a conventional ammonia applicator applies "hot" ammonia there is a considerable amount of liquid ammonia delivered to the soil once the

applicator system's temperature begins to cool down to the temperature of the expanding ammonia vapor. Ammonia vapor is approximately the same temperature as the cold liquid ammonia, -33^{o}C. The amount of liquid ammonia delivered to the soil depends on how the system is designed, length and diameter of the hoses, size of the flow divider, outside temperature and rate at which the ammonia is applied. No attempt was made to determine the actual amount of liquid produced by the implements in these studies. There was, however, considerable pressure at the point of release with the conventional applicator.

Further consideration should be given to applying conventional ammonia with a field cultivator, disc or chisel plow. New equipment accessories for applying ammonia with tillage implements has enhanced these methods of ammonia application.

Soil conditions should also be considered when using these types of equipment to apply ammonia. When soil conditions are excessively moist or dry and cloddy, retention of the ammonia may be difficult because of the poor seal of the NH_3 into the soil. General soil conditions in these studies were in optimum condition for good ammonia retention due to the tillage operations explained earlier in the materials and methods section.

Soil profile sampling data indicated no differences in the sizes of ammonia retention zones between methods of application. Distribution of ammonia between points of release were quite variable even with the conventional ammonia applicator.

A possible advantage to Cold-Flo technique is in areas of high rainfall such as the cornbelt. The shallow placement of ammonia with a tillage implement would allow earlier entry into a field where it would be too wet to apply ammonia with a conventional shank applicator but the ammonia should be covered with at least 10 cm of soil. Another advantage would be the greater width of the applicator without increasing the draft requirement of a given horsepower tractor.

Fuel consumption for different tillage operations have been calculated in liters per hectare of diesel fuel; discing - 8.1 liters/ha; field cultivator - 5.4 liters/ha; chisel plow - 10.2 liters/ha and conventional shank ammonia - 6.0 liters/ha. The use of a tillage implement to apply ammonia would eliminate a trip over a field thus saving time and money while possibly reducing compaction problems. More work is needed with shallow placement of ammonia under field conditions to see if Cold-Flo does have an advantage.

LITERATURE CITED

1. Barrer, R.M. and D.M. MacLeod. 1954. Intercalation and sorption by montmorillonite. Faraday Soc., Trans. (London). 50:980-989.

2. Blue, W.G. and C.F. Eno. 1954. Distribution and retention of anhydrous ammonia in sandy soils. Soil Science Society of America. Proc. 18:420-424.

3. Cornet, I. 1943. Sorption of ammonia on montmorillonitic clay. J. Chem. Phys. 11:217-226.

4. Graham, E.R. 1948. Determination of soil organic matter by means of a photoelectric colorimeter. Soil Sci. 65:181-183.

5. Kemp, K.E., G.W. Wallingford, B.R. Asrabadi and M. Love. 1976. A user's guide for a plotter program pacakge for the IBM 360-70. Cont. No. 239, Dept. of Stat., Statistical Laboratory, Kansas State University, Manhattan, Kansas.

6. Lamond, R.E. 1978. Effects of nitrogen form, magnesium application and soil temperature on grass tetany related components of winter wheat and tall fescue. (Unpubl. Ph.D. Dissertation), Kansas State University, Manhattan, Kansas.

7. Linder, R.C. and C.P. Harley. 1942. A rapid method for the determination of nitrogen in plant tissue. Science. 96: 565-566.

8. McDowell, L.L. and G.E. Smith. 1958. The retention and reactions of anhydrous ammonia on different soil types. Soil Science Society of America Proc. 22:38-42.

9. McVicker, M.H., Martin, W.P., Miles, I.E. and H.H. Tucker. 1965. Properties of anhydrous ammonia. p. 22. Agricultural Anhydrous Ammonia Technology and Use. Agricultural Ammonia Institute, Memphis, Tenn., the American Society of Agronomy and the Soil Science Society of America, Madison, Wisc.

10. North Central Regional Publication No. 221. North Dakota Agricultural Experiment Station, North Dakota State University, Fargo, North Dakota.

11. Parr, J.F. and J.C. Engibous. 1967. Distribution patterns of ammonia in the soils. Agron. Ammonia News. 17:62-65.

12. Parr, J.F. and R.I. Papendick. 1966. Retention of ammonia in soils. Agricultural Anhydrous Ammonia Technology and Use. pp. 213-236. Agricultural Ammonia Institute, Memphis, Tenn., the American Society of Agronomy and the Soil Science Society of America, Madison, Wisc.

13. Sohn, J.B. and M. Peech. 1958. Retention and fixation of ammonia by soils. Soil Science. 85:1-9.

14. Swart, C. 1970. Retention patterns and loss of anhydrous ammonia applied with an undercutting blade. (Unpubl. Master's Thesis), Kansas State University, Manhattan, Kansas.

15. Technicon Industrial Systems. 1977. Industrial method no. 334-74 w/B+, pp. 1-7. Individual/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Tarrytown, N.Y.

16. Technicon Industrial Systems. 1977. Industrial method no. 487-77A, pp. 1-6. Nitrate and nitrite in soil extracts. Tarrytown, N.Y.

17. Young, J.L. and B.L. McNeal. 1964. Ammonia and ammonium reactions with some layer-silicate minerals. Soil Science Society of America Proc. 28:334-339.

APPENDIX

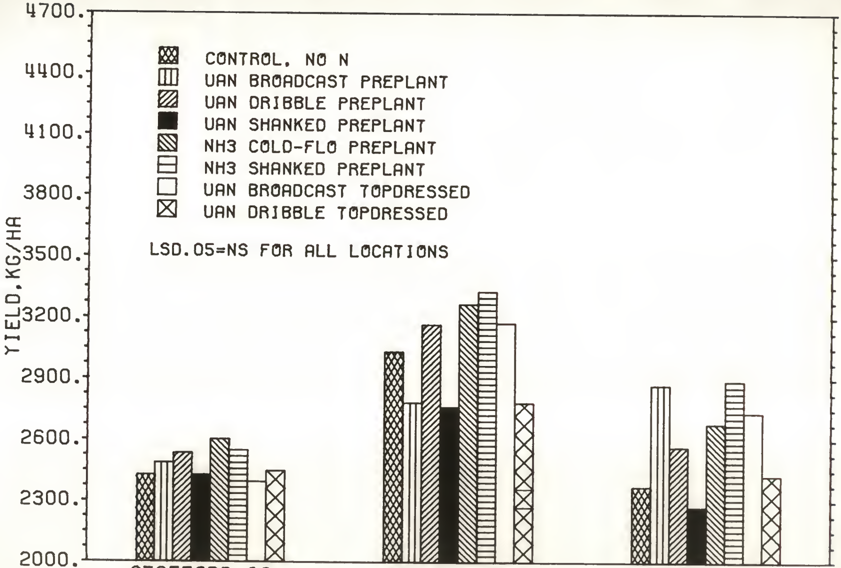


Fig. 1 EFFECTS OF AMMONIA APPLICATION METHODS ON WHEAT YIELDS, 1977.

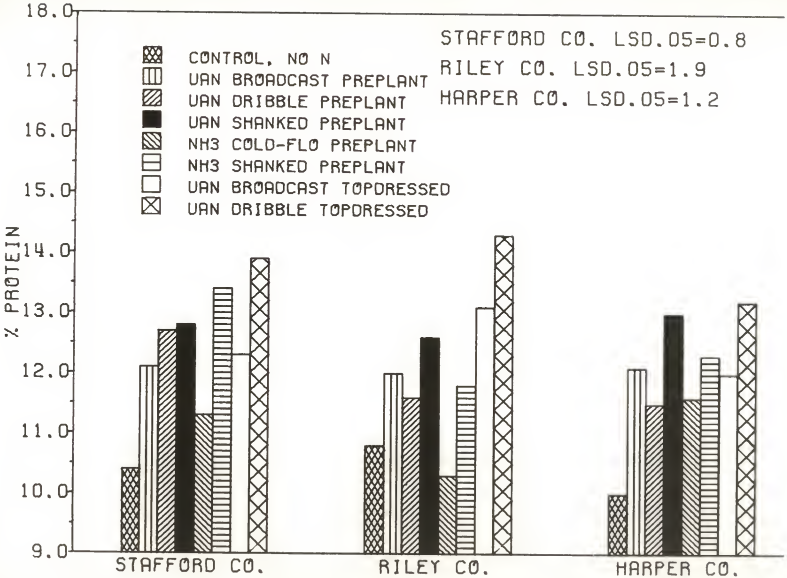


Fig. 2 EFFECTS OF AMMONIA APPLICATION METHODS ON WHEAT PROTEIN, 1977.

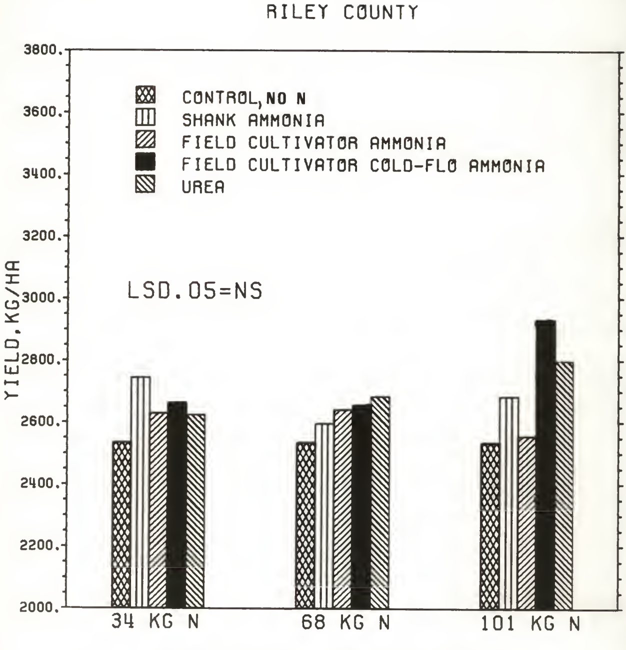


Fig. 3 EFFECTS OF AMMONIA APPLICATION METHODS ON WHEAT YIELD, 1978.

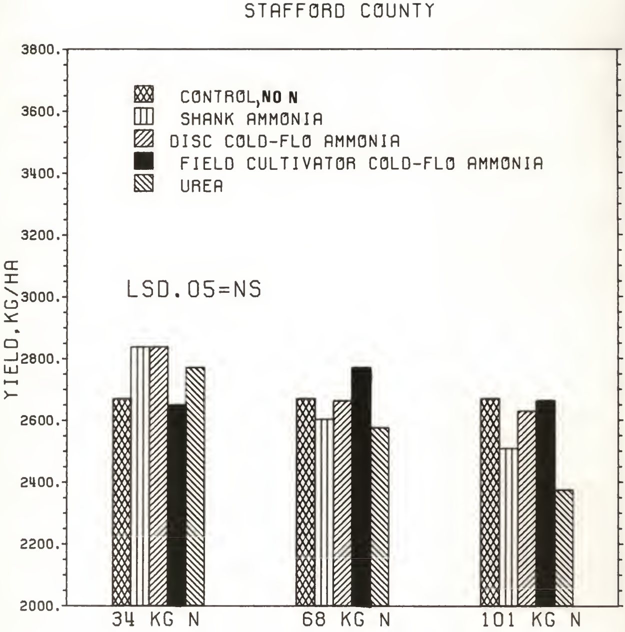


Fig. 4 EFFECTS OF AMMONIA APPLICATION METHODS ON WHEAT YIELD,1978.

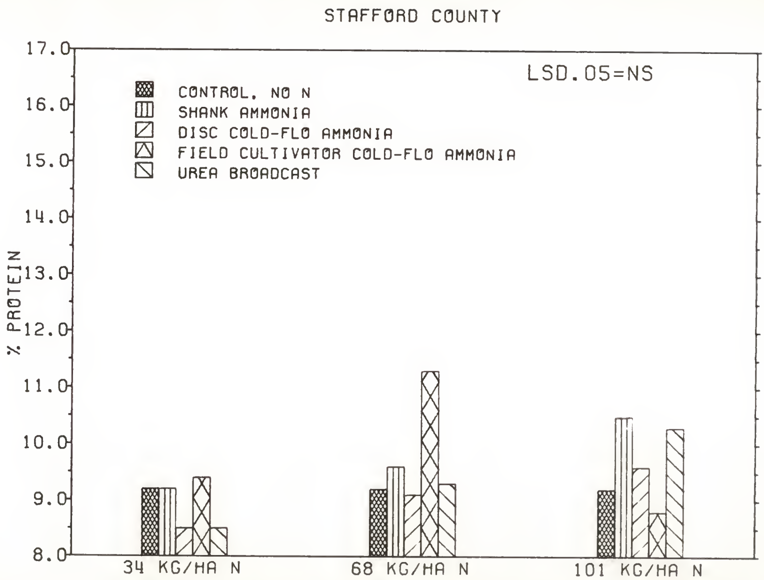


Fig. 5 EFFECTS OF AMMONIA APPLICATION METHODS ON WHEAT PROTEIN, 1978.

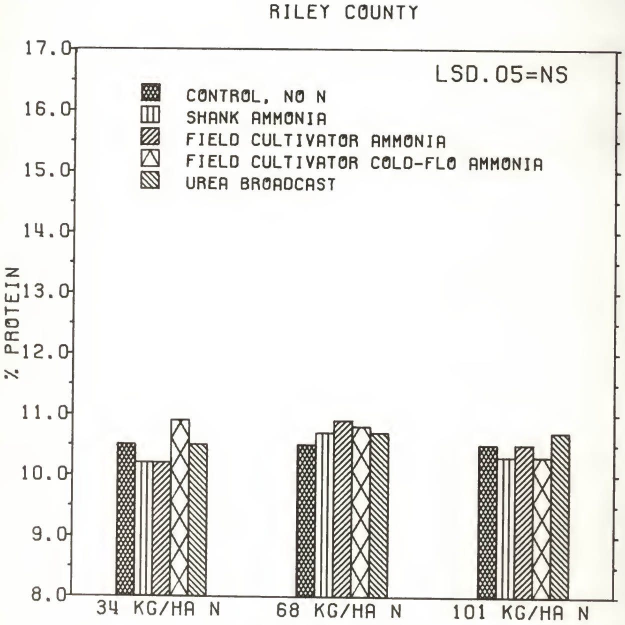


Fig. 6 EFFECTS OF AMMONIA APPLICATION METHODS ON WHEAT PROTEIN, 1978.

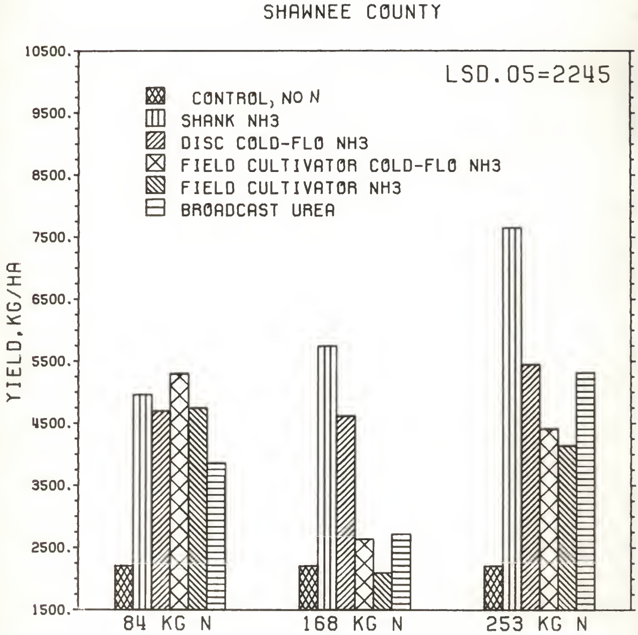


Fig. 7 EFFECTS OF AMMONIA APPLICATION METHODS ON CORN YIELDS, 1977.

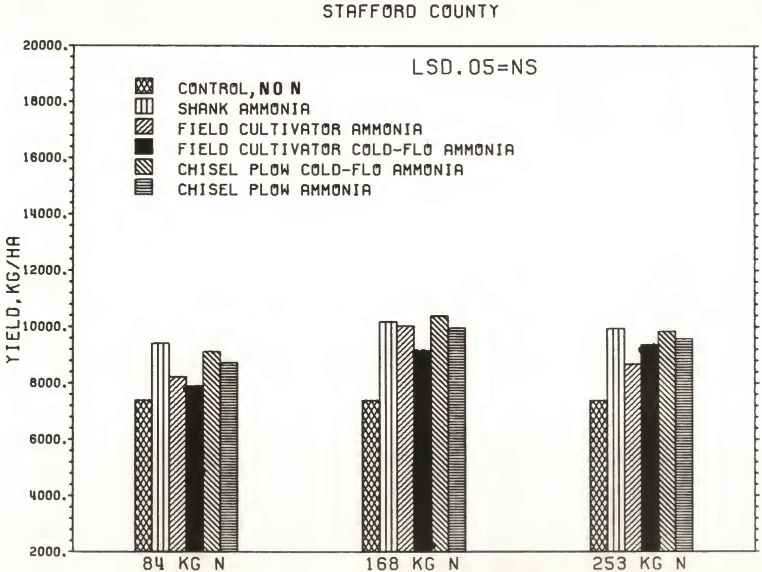


Fig. 8 EFFECTS OF AMMONIA APPLICATION METHODS ON IRRIGATED CORN, 1978.

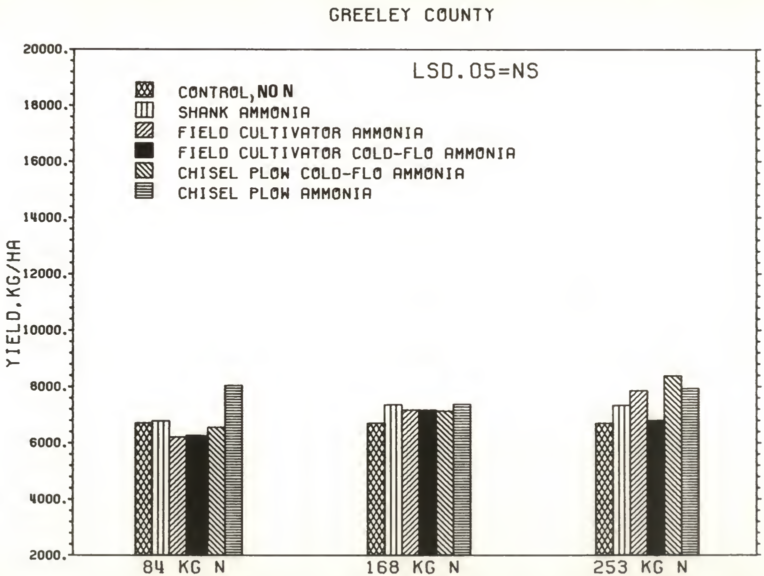


Fig. 9 EFFECTS OF AMMONIA APPLICATION METHODS ON IRRIGATED CORN,1978.

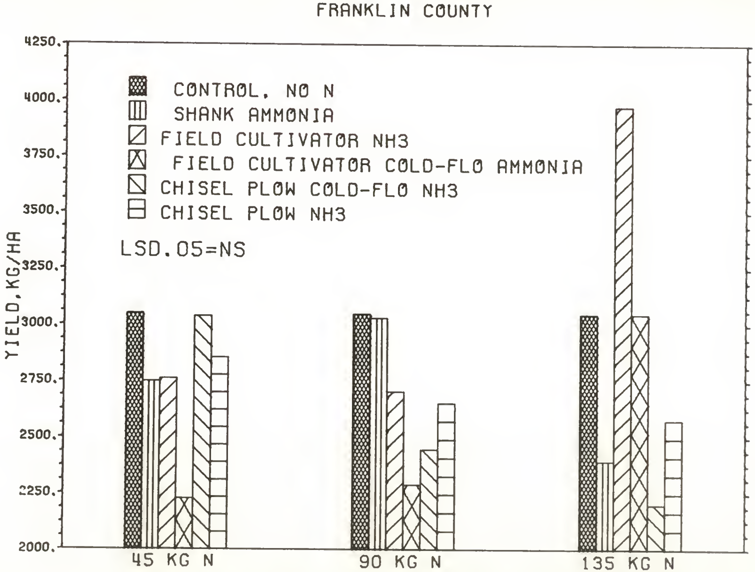


Fig. 10 EFFECTS OF AMMONIA APPLICATION ON GRAIN SORGHUM YIELDS, 1978.

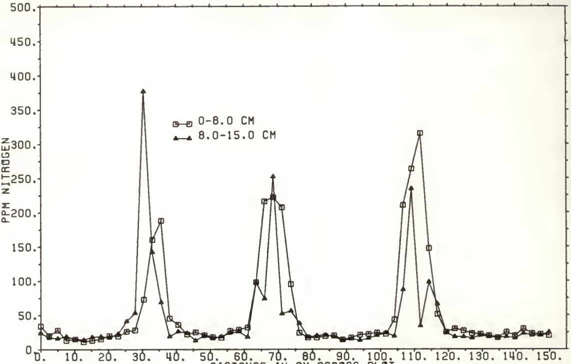


Fig. 11 NITROGEN CONCENTRATIONS IN SOIL PROFILE.
135 KG/HA OF N AS AMMONIA(FIELD CULTIVATOR).

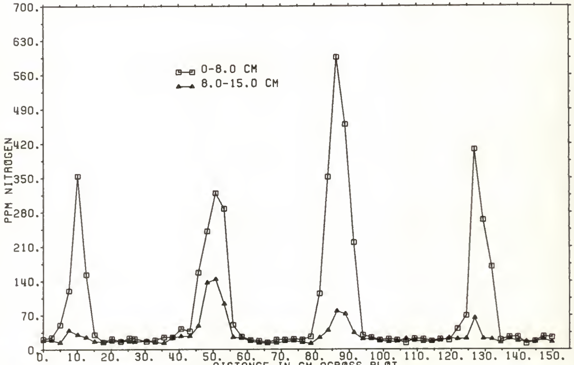


Fig. 12 NITROGEN CONCENTRATIONS IN SOIL PROFILE.
135 KG/HA OF N AS COLD-FLO AMMONIA(FIELD CULTIVATOR).

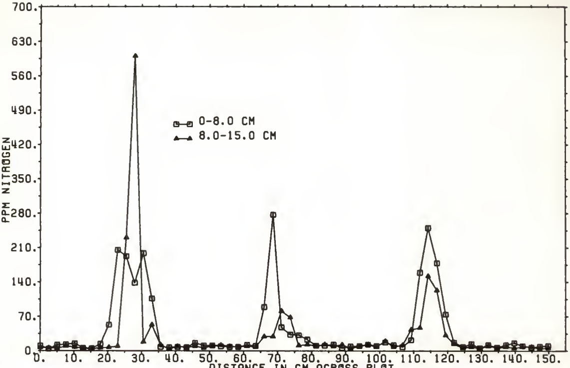


Fig. 13 NITROGEN CONCENTRATIONS IN SOIL PROFILE.
135 KG/HA OF N AS AMMONIA (SHANK).

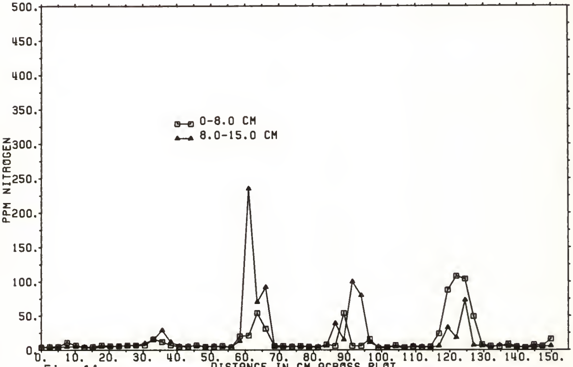


Fig. 14 NITROGEN CONCENTRATIONS IN SOIL PROFILE.
135 KG/HA OF N AS COLD-FLO AMMONIA (CHISEL PLOW).

Table I. Soil Profile Sampling Data. Field Cultivator with Cold-Flo Ammonia 135 Kg N/ha. Samples were taken 10 days after application of ammonia. (Ashland Agronomy Farm).

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
1-1	5.0	16.4	21.4	11-1	16.0	6.7	22.7
2	8.5	9.4	17.4	2	10.9	5.1	16.0
3	5.5	6.8	12.3	3	7.4	5.1	12.5
4	8.6	6.3	14.9	4	8.2	5.5	13.7
2-1	8.2	16.7	24.9	12-1	13.5	7.8	21.3
2	6.6	11.5	18.1	2	8.5	6.0	14.5
3	7.0	7.5	14.5	3	8.2	5.8	14.0
4	5.4	6.2	11.6	4	8.9	4.6	13.5
3-1	26.2	25.0	51.2	13-1	9.0	6.5	15.5
2	4.4	9.8	14.2	2	11.5	5.9	17.4
3	6.7	6.8	13.5	3	7.6	5.5	13.1
4	6.1	7.1	13.2	4	7.5	5.7	13.2
4-1	80.5	39.5	120.0	14-1	10.6	7.5	18.1
2	16.0	22.8	38.8	2	6.8	6.6	13.4
3	11.4	14.4	25.8	3	9.3	6.2	15.5
4	5.3	6.9	12.2	4	10.3	5.7	16.0
5-1	315.0	39.4	364.4	15-1	16.9	8.2	25.1
2	15.5	14.4	29.9	2	7.4	5.9	13.3
3	8.5	9.5	18.0	3	7.3	5.7	13.0
4	5.3	8.0	13.3	4	7.8	6.2	14.0
6-1	118.0	35.0	153.0	16-1	15.5	9.0	24.5
2	9.5	14.8	24.3	2	15.3	8.3	23.6
3	6.6	10.4	17.0	3	11.5	5.4	16.9
4	10.0	7.7	17.7	4	10.0	5.0	15.0
7-1	15.2	15.0	30.2	17-1	13.3	28.0	41.2
2	7.3	8.3	15.6	2	11.6	14.9	36.5
3	7.0	7.3	14.3	3	9.5	7.0	16.5
4	7.6	5.3	12.9	4	6.2	7.4	13.6
8-1	6.2	9.2	15.4	18-1	13.3	23.7	37.0
2	7.0	8.3	15.3	2	13.5	13.5	27.0
3	10.0	9.5	19.5	3	10.7	7.8	18.5
4	8.2	7.3	15.5	4	9.6	6.7	16.3
9-1	10.2	11.5	21.7	19-1	80.0	77.4	157.4
2	8.8	6.8	15.6	2	23.6	24.2	47.8
3	7.3	6.9	14.2	3	8.3	7.6	15.9
4	8.3	7.9	16.2	4	7.2	7.0	14.0
10-1	10.3	6.1	16.4	20-1	176.0	64.8	240.8
2	9.8	6.5	16.3	2	83.0	54.0	137.0
3	7.1	6.3	13.4	3	8.1	8.0	16.1
4	11.0	4.5	15.5	4	7.5	6.1	13.6

Table I (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
21-1	275.0	44.0	319.0	32-1	13.8	12.0	25.8
2	104.4	40.3	144.7	2	5.0	6.9	11.9
3	13.2	7.8	21.0	3	8.0	7.1	15.1
4	9.3	6.0	15.3	4	8.8	5.3	14.1
22-1	225.0	62.0	287.0	33-1	68.4	45.6	114.0
2	56.0	37.0	93.0	2	10.0	13.5	23.5
3	8.3	8.8	17.1	3	7.2	8.1	15.3
4	11.0	9.1	20.1	4	12.0	6.2	18.2
23-1	17.5	32.8	50.3	34-1	277.0	75.0	352.0
2	8.5	16.8	25.3	2	21.4	17.7	39.1
3	11.7	8.4	20.1	3	8.3	8.4	16.7
4	7.4	6.5	13.9	4	5.7	7.0	12.7
24-1	10.5	15.9	26.4	35-1	560.0	36.0	596.0
2	10.8	12.5	33.3	2	47.7	29.9	77.6
3	6.0	8.3	14.3	3	8.0	8.4	16.4
4	6.6	5.7	12.3	4	10.3	7.0	17.3
25-1	10.1	9.2	19.3	36-1	430.0	28.5	458.5
2	7.8	10.0	17.8	2	47.8	24.4	72.2
3	8.0	7.7	15.7	3	8.5	9.8	18.3
4	9.0	6.6	15.6	4	8.0	6.5	14.5
26-1	10.5	7.1	17.6	37-1	169.0	49.2	218.2
2	5.8	7.3	13.1	2	19.3	14.6	33.9
3	9.2	5.8	15.0	3	20.5	10.5	31.0
4	10.0	5.9	15.9	4	9.8	6.1	15.9
27-1	6.8	7.4	14.2	38-1	12.1	16.5	28.6
2	7.2	6.1	13.3	2	8.8	12.2	21.0
3	8.1	5.6	13.7	3	7.5	9.7	17.2
4	7.0	6.4	13.4	4	9.0	6.1	15.1
28-1	12.5	7.5	19.7	39-1	13.3	10.9	24.2
2	7.2	6.1	13.3	2	9.8	11.4	21.2
3	5.3	6.6	11.9	3	7.5	9.2	16.7
4	7.5	6.0	13.5	4	10.5	7.7	18.2
29-1	11.0	9.4	20.4	40-1	10.8	8.4	19.2
2	8.8	7.0	15.8	2	8.4	9.8	18.2
3	8.0	5.3	13.3	3	8.9	9.5	18.4
4	12.5	5.9	18.4	4	9.5	7.0	16.5
30-1	11.9	9.0	20.9	41-1	12.3	8.5	20.8
2	10.8	5.5	16.3	2	7.7	7.0	14.7
3	8.7	5.8	14.5	3	8.8	7.2	16.0
4	6.4	6.1	12.5	4	6.2	5.6	11.8
31-1	8.6	10.9	19.5	42-1	10.7	7.7	18.3
2	6.2	8.1	14.3	2	8.5	7.1	15.6
3	8.2	6.8	15.0	3	7.6	7.4	15.0
4	8.7	5.5	14.2	4	9.1	5.6	14.7

Table I (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
43-1	5.5	6.9	12.4	52-1	219.0	45.2	264.2
2	15.0	7.0	22.0	2	9.2	12.7	21.9
3	11.7	6.5	18.2	3	8.0	7.5	15.5
4	8.2	5.8	14.0	4	9.2	5.9	15.1
44-1	12.9	8.6	21.5	53-1	125.0	44.0	169.0
2	10.2	7.3	17.5	2	8.0	13.0	21.0
3	7.5	6.4	13.9	3	6.3	6.5	12.8
4	6.5	6.5	13.0	4	10.4	6.2	16.6
45-1	13.5	7.0	20.5	54-1	8.4	11.1	19.5
2	8.0	6.5	14.5	2	5.0	8.6	13.6
3	9.3	7.3	16.6	3	5.7	6.7	12.4
4	8.4	6.5	14.9	4	11.5	7.5	19.0
46-1	8.5	8.2	16.7	55-1	11.3	14.8	26.1
2	7.8	7.7	15.5	2	13.0	9.2	22.2
3	7.0	6.7	13.7	3	7.1	8.7	15.8
4	7.4	6.7	14.1	4	10.4	7.4	17.8
47-1	12.6	8.4	21.0	56-1	14.9	10.5	25.4
2	9.1	9.0	18.1	2	8.8	8.2	17.0
3	6.8	7.2	14.0	3	9.0	7.8	16.8
4	7.3	6.5	13.8	4	11.0	5.9	16.9
48-1	8.6	9.9	18.5	57-1	13.1	11.6	24.7
2	12.3	10.5	22.8	2	8.6	7.4	16.0
3	14.5	8.2	22.7	3	6.5	6.1	12.6
4	6.7	7.0	13.7	4	8.5	6.2	14.7
49-1	20.0	21.8	41.8	58-1	8.0	8.7	16.7
2	9.7	11.3	21.0	2	8.4	7.9	16.3
3	9.2	8.1	17.3	3	8.7	6.5	15.2
4	9.9	6.5	16.4	4	8.9	5.1	14.0
50-1	39.6	29.4	69.0	59-1	15.9	11.4	27.3
2	9.3	13.0	22.3	2	11.3	9.5	20.8
3	8.4	8.8	17.2	3	8.6	7.4	16.0
4	8.2	6.7	14.9	4	9.5	5.2	14.7
51-1	363.0	44.6	407.6	60-1	14.3	10.8	25.1
2	40.5	23.3	63.8	2	8.4	6.7	15.1
3	10.2	8.8	19.0	3	9.0	5.5	14.5
4	9.5	7.7	17.2	4	9.4	4.5	13.9

*All values are reported in ppm.

Table II. Soil Profile Sampling Data. Field Cultivator with Ammonia 135 Kg N/ha. Samples were taken 10 days after application of ammonia. (Ashland Agronomy Farm).

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
1-1	14.2	19.8	34.0	11-1	10.0	16.4	26.4
2	11.1	12.9	24.0	2	14.7	26.0	30.7
3	7.4	9.8	17.2	3	6.0	10.8	15.8
4	5.9	7.1	13.0	4	7.0	9.0	16.0
2-1	7.0	13.0	20.0	12-1	9.8	17.5	27.3
2	4.7	12.0	16.7	2	20.9	32.3	53.2
3	8.0	8.7	16.7	3	7.2	15.3	22.5
4	7.6	7.8	15.4	4	12.7	11.6	24.3
3-1	17.7	9.6	27.3	13-1	40.4	32.5	72.9
2	5.4	11.1	16.5	2	325.0	52.2	372.4
3	4.6	8.3	12.9	3	9.7	11.8	21.5
4	10.8	7.0	17.8	4	8.3	8.7	17.0
4-1	5.2	7.7	12.9	14-1	100.0	60.0	160.0
2	8.0	11.4	18.4	2	103.0	38.7	141.7
3	6.5	8.0	14.5	3	7.8	15.3	23.1
4	4.6	7.0	11.7	4	10.0	11.2	21.2
5-1	7.3	7.8	15.1	15-1	137.0	50.6	187.6
2	4.2	10.4	14.6	2	41.3	27.1	68.4
3	8.8	7.3	16.1	3	7.8	11.7	19.5
4	5.5	6.5	12.1	4	6.2	7.8	14.0
6-1	4.5	6.6	11.1	16-1	17.6	27.2	43.8
2	3.4	10.3	13.7	2	4.7	13.7	18.4
3	9.0	8.2	17.2	3	10.0	9.8	19.8
4	10.4	7.5	17.9	4	10.5	8.3	18.8
7-1	4.5	8.3	12.8	17-1	15.7	20.0	35.7
2	8.0	9.8	17.8	2	11.5	14.3	25.8
3	5.5	7.3	13.8	3	9.3	8.3	17.6
4	6.8	6.8	13.6	4	12.7	8.2	20.9
8-1	7.0	7.5	14.5	18-1	9.0	13.0	22.0
2	9.5	9.3	18.8	2	13.5	10.4	23.9
3	6.2	9.4	15.6	3	5.8	8.7	14.5
4	8.7	7.4	16.1	4	10.3	7.6	17.9
9-1	10.5	9.3	19.8	19-1	14.1	11.1	25.2
2	7.9	9.4	17.3	2	5.0	8.0	13.0
3	5.8	6.7	12.5	3	7.5	8.3	15.8
4	9.3	7.5	16.8	4	5.7	7.6	13.3
10-1	10.3	9.0	19.3	20-1	11.2	9.6	20.8
2	8.7	14.2	22.9	2	10.4	9.3	19.7
3	6.5	12.3	17.8	3	9.4	7.0	16.4
4	7.8	8.9	16.7	4	6.0	7.0	13.0

Table II (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
21-1	9.4	8.9	13.3	32-1	5.2	12.2	17.4
2	7.4	8.2	15.6	2	6.4	11.5	17.9
3	9.0	7.2	16.2	3	5.9	7.7	13.6
4	7.1	6.2	13.3	4	10.5	5.9	16.4
22-1	6.1	10.5	16.6	33-1	8.7	8.5	17.2
2	8.3	10.2	18.5	2	9.5	10.4	19.9
3	9.5	7.9	17.4	3	5.6	7.9	13.5
4	5.3	7.5	12.8	4	8.2	6.5	14.7
23-1	15.2	11.6	26.8	34-1	10.2	8.7	18.9
2	15.0	9.3	24.3	2	12.5	8.9	21.4
3	7.7	7.2	14.9	3	7.9	7.5	15.4
4	7.5	6.9	14.4	4	10.0	5.5	15.5
24-1	11.4	17.5	28.9	35-1	11.5	8.3	19.8
2	14.1	11.4	25.4	2	8.0	9.9	17.9
3	6.6	6.8	13.4	3	10.2	6.4	16.6
4	10.4	6.5	16.9	4	6.4	5.3	11.7
25-1	8.5	23.7	32.2	36-1	6.5	6.8	13.3
2	5.0	13.2	18.2	2	6.4	6.1	12.5
3	9.5	10.1	19.6	3	5.5	6.3	11.8
4	10.2	8.0	18.2	4	9.2	4.3	13.5
26-1	63.8	33.8	97.6	37-1	8.5	8.2	16.7
2	65.6	32.7	98.3	2	6.5	8.0	14.5
3	13.1	9.5	22.6	3	6.9	7.4	14.3
4	17.3	6.7	24.0	4	6.1	6.1	12.2
27-1	176.4	40.2	216.6	38-1	11.5	8.8	20.3
2	47.6	26.5	74.1	2	5.3	7.4	12.7
3	10.5	11.0	21.5	3	5.8	7.2	13.0
4	10.3	8.2	18.5	4	8.6	6.0	14.6
28-1	192.0	30.3	222.3	39-1	9.3	12.8	22.1
2	228.0	23.6	251.6	2	6.3	9.7	16.0
3	7.4	8.7	16.1	3	7.8	7.6	15.4
4	8.0	7.0	15.0	4	6.5	7.0	13.5
29-1	172.0	34.9	206.9	40-1	11.5	12.4	23.9
2	27.7	23.8	31.5	2	9.3	11.0	20.3
3	6.6	9.3	15.9	3	7.6	8.6	16.2
4	6.2	11.6	17.8	4	6.1	6.8	12.9
30-1	64.2	31.3	95.5	41-1	9.0	12.8	21.8
2	32.7	23.4	56.1	2	9.8	14.4	24.2
3	7.3	9.7	17.0	3	8.7	9.0	17.7
4	9.1	7.7	16.8	4	10.0	6.5	16.5
31-1	10.3	13.5	23.8	42-1	20.5	21.9	42.4
2	17.0	21.4	38.4	2	7.0	11.7	18.7
3	8.0	11.0	19.0	3	6.5	8.3	14.8
4	10.2	8.3	18.5	4	13.0	5.7	18.7

Table II (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
43-1	172.5	37.3	209.9	52-1	10.4	11.1	21.4
2	57.8	29.5	87.3	2	10.2	10.1	20.3
3	10.2	11.5	21.7	3	6.5	8.2	14.7
4	12.5	7.9	20.4	4	8.8	6.9	15.7
44-1	231.0	31.6	262.6	53-1	10.5	9.4	19.9
2	189.2	45.2	234.4	2	9.6	8.2	17.8
3	15.2	12.3	27.5	3	8.7	7.6	16.3
4	8.5	7.9	16.4	4	10.7	6.6	17.3
45-1	272.0	42.8	314.8	54-1	6.2	10.7	16.9
2	15.6	18.3	33.9	2	6.7	9.5	16.2
3	9.8	11.3	21.1	3	9.2	7.3	16.5
4	13.0	9.5	21.5	4	7.0	6.1	13.1
46-1	105.0	41.7	146.7	55-1	15.4	9.8	25.2
2	69.0	29.3	98.3	2	10.0	8.2	18.2
3	15.4	12.5	27.9	3	11.2	7.3	18.5
4	16.2	11.0	27.2	4	11.3	6.3	17.6
47-1	29.3	21.9	51.2	56-1	7.5	11.8	19.3
2	29.9	36.0	65.9	2	6.5	9.0	15.5
3	13.2	17.7	30.9	3	6.8	7.3	14.1
4	11.3	10.5	21.8	4	7.0	6.7	13.7
48-1	7.5	16.9	24.4	57-1	18.1	11.9	30.0
2	8.7	14.7	23.4	2	13.7	9.1	22.8
3	7.6	11.4	19.0	3	9.9	7.0	16.9
4	9.0	10.2	19.2	4	11.0	6.6	17.6
49-1	17.4	12.7	30.1	58-1	10.3	12.9	23.2
2	5.5	12.2	17.7	2	9.2	11.1	20.3
3	6.1	8.7	14.8	3	8.5	7.6	16.1
4	7.0	8.3	15.3	4	8.8	6.1	14.9
50-1	14.6	12.6	27.2	59-1	12.0	10.5	22.5
2	5.4	12.3	17.7	2	8.6	11.1	19.7
3	6.5	10.8	17.3	3	10.5	7.4	17.9
4	6.8	7.3	14.4	4	11.2	6.5	17.7
51-1	13.1	9.5	22.6	60-1	8.5	11.4	19.9
2	6.1	10.3	16.4	2	11.9	12.7	24.6
3	10.3	7.0	17.3	3	10.2	7.2	17.4
4	6.5	7.4	11.9	4	10.1	7.1	17.2

*All values are reported in ppm.

Table III. Soil Profile Sampling Data. Shank Ammonia 135 Kg N/ha. Samples were taken 10 days after Application of Ammonia. (Ashland Agronomy Farm).

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
1-1	9.6	5.7	15.3	11-1	192.0	31.8	223.8
2	6.4	6.0	12.4	2	230.0	37.0	267.0
3	5.9	4.7	10.6	3	14.7	11.3	26.0
4	8.8	5.0	13.8	4	16.5	9.0	25.5
2-1	3.5	6.7	10.2	12-1	137.6	42.4	180.0
2	6.2	6.0	12.2	2	600.0	42.5	642.5
3	7.7	4.0	11.7	3	16.4	14.0	30.4
4	9.0	4.2	13.2	4	11.1	8.5	19.6
3-1	11.8	6.6	18.4	13-1	198.0	43.0	241.0
2	5.3	6.9	12.2	2	17.5	13.5	31.0
3	4.2	5.7	9.9	3	8.8	7.8	16.5
4	12.3	4.8	17.1	4	9.8	7.5	17.3
4-1	13.4	7.5	20.9	14-1	58.7	44.0	102.7
2	8.8	7.5	16.3	2	53.4	38.9	92.3
3	5.5	9.4	14.9	3	8.5	13.1	21.6
4	5.0	5.0	10.0	4	5.8	8.6	14.4
5-1	15.0	6.5	21.5	15-1	7.5	12.9	20.4
2	6.8	6.8	13.8	2	12.2	16.7	28.9
3	7.2	5.0	12.0	3	5.0	10.5	15.5
4	4.7	4.5	9.2	4	6.4	7.0	13.4
6-1	6.1	6.3	12.4	16-1	7.2	7.5	14.7
2	4.7	7.5	12.2	2	4.1	10.2	14.3
3	4.6	5.5	10.1	3	6.1	8.0	14.1
4	8.0	4.0	12.0	4	7.0	7.4	14.4
7-1	5.0	6.2	11.2	17-1	7.5	7.6	15.1
2	3.7	7.7	11.4	2	8.5	8.7	17.2
3	8.2	8.0	15.2	3	5.1	7.2	12.3
4	10.0	5.2	15.2	4	9.3	7.0	16.3
8-1	13.6	11.7	25.3	18-1	7.4	7.5	14.9
2	6.1	11.5	17.6	2	7.8	8.8	15.6
3	6.4	7.4	13.8	3	4.5	8.0	12.5
4	5.0	5.4	10.4	4	7.9	6.6	14.5
9-1	53.2	30.9	84.1	19-1	16.3	7.1	23.4
2	6.5	18.3	24.8	2	9.1	8.8	17.9
3	8.2	8.0	16.2	3	8.3	6.3	14.6
4	4.6	6.5	11.1	4	12.5	5.3	17.8
10-1	205.0	53.4	258.4	20-1	11.2	7.8	19.0
2	9.1	9.2	18.3	2	6.2	9.9	16.1
3	6.4	7.1	13.5	3	9.4	6.0	15.4
4	15.0	8.1	23.1	4	10.3	5.2	15.5

Table III (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
21-1	10.7	7.5	18.2	32-1	22.8	15.8	38.6
2	10.0	10.4	20.4	2	13.3	19.6	32.9
3	6.4	7.1	13.4	3	10.7	11.0	21.7
4	12.6	4.7	17.3	4	12.4	9.0	21.4
22-1	9.2	7.8	17.0	33-1	10.7	10.0	20.7
2	13.3	9.9	22.2	2	9.8	11.3	21.1
3	3.8	7.6	11.4	3	10.0	8.2	18.2
4	7.6	5.5	13.1	4	9.8	5.7	15.5
23-1	7.5	8.3	15.8	34-1	10.6	7.7	18.3
2	8.9	9.7	18.6	2	12.6	11.5	34.1
3	8.6	8.2	16.8	3	10.0	6.9	16.9
4	9.3	6.4	15.7	4	7.7	5.3	13.0
24-1	7.5	8.5	16.0	35-1	13.3	7.7	21.0
2	8.3	11.2	19.5	2	9.0	10.0	19.0
3	7.4	6.8	14.2	3	7.4	9.0	16.4
4	8.7	5.6	13.3	4	9.8	6.2	16.0
25-1	12.2	20.2	32.4	36-1	5.5	8.6	14.1
2	8.9	18.5	27.4	2	13.0	9.7	22.7
3	6.9	9.4	16.3	3	8.6	8.6	17.2
4	9.5	6.3	15.8	4	10.5	6.7	17.2
26-1	10.3	32.2	42.5	37-1	7.2	8.7	15.9
2	7.5	18.5	26.0	2	5.4	9.3	14.7
3	5.7	9.2	14.9	3	9.4	7.7	17.1
4	9.9	7.2	17.1	4	11.5	6.1	17.6
27-1	88.6	74.8	163.4	38-1	9.7	7.5	17.2
2	28.5	25.7	54.2	2	9.0	8.6	17.6
3	15.9	9.3	25.2	3	15.3	8.9	24.2
4	13.6	9.0	22.6	4	6.8	6.9	13.7
28-1	277.0	82.0	359.0	39-1	12.8	7.4	20.2
2	29.0	35.8	64.8	2	12.8	9.2	22.0
3	5.6	9.5	15.1	3	9.7	10.4	20.1
4	8.8	6.5	15.3	4	8.8	6.7	15.5
29-1	48.0	71.6	119.6	40-1	10.0	7.1	17.1
2	80.6	42.3	122.9	2	8.2	8.3	16.5
3	8.5	9.2	17.7	3	10.5	7.1	17.6
4	11.2	7.0	18.2	4	8.2	5.4	13.6
30-1	32.7	38.8	71.5	41-1	16.5	7.6	24.1
2	68.2	22.3	90.5	2	19.8	9.6	29.4
3	8.5	7.7	16.2	3	9.8	9.4	19.2
4	12.1	7.5	19.6	4	11.2	6.8	18.0
31-1	31.2	29.7	60.9	42-1	11.5	8.1	19.6
2	11.2	16.5	27.7	2	8.2	10.7	18.9
3	10.2	9.2	19.4	3	8.1	8.7	16.8
4	13.8	7.0	20.8	4	10.7	5.6	16.3

Table III (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
43-1	7.5	9.0	16.5	52-1	5.5	7.4	12.9
2	12.1	17.3	29.4	2	4.8	10.3	21.1
3	10.0	9.5	19.5	3	9.4	6.8	16.2
4	7.8	6.7	14.5	4	8.7	7.0	15.7
44-1	22.0	33.2	55.2	53-1	12.0	9.0	21.0
2	42.5	42.2	84.7	2	9.8	9.9	19.7
3	13.3	10.7	24.0	3	10.0	8.2	18.2
4	7.8	13.8	21.6	4	13.3	5.8	14.1
45-1	159.6	75.0	234.6	54-1	6.6	10.3	16.9
2	46.7	31.0	77.7	2	5.5	10.0	15.5
3	16.2	10.7	26.9	3	17.7	8.2	25.9
4	9.4	8.2	17.6	4	8.0	7.0	15.0
46-1	250.0	91.8	341.8	55-1	12.3	9.6	21.9
2	151.6	43.2	194.8	2	8.2	9.7	17.9
3	12.7	10.5	23.2	3	6.2	7.5	13.7
4	9.0	6.3	15.3	4	8.8	6.3	15.1
47-1	178.0	87.6	265.6	56-1	15.9	12.2	28.1
2	122.6	55.6	178.2	2	5.8	7.8	13.6
3	9.0	9.8	18.8	3	6.4	7.3	13.7
4	10.0	6.7	16.7	4	5.8	5.7	11.5
48-1	74.0	56.0	130.0	57-1	10.4	10.5	20.9
2	31.7	29.2	60.9	2	7.9	9.4	17.3
3	11.0	8.3	19.3	3	9.0	7.1	16.1
4	13.2	6.0	19.2	4	14.0	5.8	19.8
49-1	11.7	10.4	22.1	58-1	7.0	11.0	18.0
2	14.2	14.3	28.5	2	7.8	9.0	16.8
3	11.3	8.7	20.0	3	9.6	8.1	17.7
4	13.5	5.6	19.1	4	5.4	6.6	12.0
50-1	8.3	7.5	15.8	59-1	8.6	8.5	17.1
2	6.3	12.2	18.5	2	4.7	10.1	14.8
3	6.8	8.7	15.5	3	6.2	7.7	13.9
4	6.8	6.8	13.6	4	8.7	5.4	14.1
51-1	13.8	6.6	20.4	60-1	11.1	10.1	21.1
2	7.8	9.3	17.1	2	6.2	10.7	16.9
3	8.8	8.0	16.8	3	8.5	6.9	15.4
4	11.2	6.0	17.2	4	7.9	5.6	13.5

*All values are reported in ppm.

Table IV. Soil Profile Sampling Data. Chisel Plow with Cold-Flo Ammonia 135 Kg N/ha. Samples were taken 10 days after Ammonia Application. (Ashland Agronomy Farm).

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
1-1	4.2	10.0	14.2	11-1	7.3	9.6	16.9
2	4.6	9.3	13.9	2	7.2	7.2	14.4
3	3.5	6.0	9.5	3	5.5	7.7	13.2
4	5.1	7.7	12.8	4	6.8	7.9	14.7
2-1	4.8	14.5	19.3	12-1	6.5	10.0	16.5
2	3.4	10.3	13.7	2	7.0	15.8	22.8
3	4.3	6.1	10.4	3	8.8	11.8	20.6
4	5.0	5.5	10.5	4	6.8	13.0	19.8
3-1	4.7	18.7	23.4	13-1	7.4	10.3	17.1
2	4.4	9.4	13.8	2	9.7	27.3	37.0
3	4.5	5.5	11.0	3	6.2	10.5	16.7
4	4.5	6.3	10.8	4	6.0	7.7	13.7
4-1	10.8	21.8	32.6	14-1	15.5	30.0	45.5
2	4.5	8.2	12.7	2	15.3	38.1	53.7
3	5.0	6.1	11.1	3	5.8	12.7	18.5
4	4.2	5.3	9.5	4	5.7	7.4	13.1
5-1	7.4	15.5	22.9	15-1	11.8	30.5	42.3
2	4.7	8.2	12.9	2	28.5	42.1	70.6
3	4.4	6.2	10.6	3	5.7	12.0	17.7
4	5.0	4.7	9.7	4	5.3	9.0	14.3
6-1	4.3	7.9	12.2	16-1	6.5	14.8	21.3
2	5.2	6.5	11.7	2	11.8	37.0	48.8
3	6.8	4.5	11.3	3	6.5	12.1	18.6
4	7.8	5.5	13.3	4	6.6	8.7	15.3
7-1	4.7	7.5	12.2	17-1	5.4	17.5	22.9
2	2.9	8.7	11.6	2	6.4	16.0	22.4
3	5.5	5.7	11.2	3	8.0	10.0	18.0
4	5.0	6.1	11.1	4	6.3	7.5	13.8
8-1	7.1	6.7	13.8	18-1	5.2	10.9	16.1
2	5.3	6.5	11.8	2	6.2	12.7	18.9
3	5.5	5.6	11.1	3	6.2	10.0	16.2
4	5.0	6.5	11.5	4	4.9	7.7	12.6
9-1	6.3	7.5	13.8	19-1	6.7	7.3	14.0
2	5.0	6.3	11.3	2	5.8	7.5	13.3
3	4.0	6.3	10.3	3	5.0	6.5	11.5
4	5.0	5.8	10.8	4	4.9	6.5	11.4
10-1	6.3	9.7	17.0	20-1	5.3	6.6	11.9
2	6.4	8.3	14.3	2	4.5	7.4	11.9
3	5.3	8.0	13.3	3	6.7	6.7	13.4
4	5.7	7.5	13.2	4	5.4	5.5	10.9

Table IV (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
21-1	4.5	7.0	11.5	32-1	4.8	7.3	12.1
2	5.5	7.0	12.5	2	5.2	7.0	12.2
3	4.9	6.4	11.3	3	6.4	6.6	13.0
4	5.1	5.7	10.8	4	5.2	5.5	10.7
22-1	5.7	7.3	13.0	33-1	4.4	8.3	12.7
2	4.2	7.3	11.5	2	5.3	10.1	15.4
3	5.0	7.5	12.5	3	5.9	7.5	13.4
4	7.2	5.7	12.0	4	5.3	6.9	12.2
23-1	4.3	13.6	17.9	34-1	8.2	8.2	16.4
2	5.2	11.5	16.7	2	5.7	17.0	22.7
3	4.8	6.7	11.5	3	6.2	8.3	14.5
4	5.4	6.3	11.7	4	6.3	5.8	12.1
24-1	19.3	34.1	53.4	35-1	5.8	10.1	15.9
2	12.8	19.5	32.3	2	39.4	37.3	76.7
3	5.6	6.7	12.3	3	5.8	10.7	16.5
4	4.5	6.7	11.2	4	4.5	7.2	11.7
25-1	20.8	37.8	58.6	36-1	54.0	21.9	75.9
2	235.0	100.0	335.0	2	15.1	14.7	29.8
3	5.0	10.5	15.5	3	6.8	7.5	14.3
4	6.2	7.9	14.1	4	7.4	6.7	14.1
26-1	54.0	49.3	103.3	37-1	6.2	12.8	19.0
2	70.0	40.1	110.1	2	100.0	14.9	114.9
3	5.8	9.1	14.9	3	5.2	13.7	18.9
4	5.0	6.6	11.6	4	4.2	8.9	13.1
27-1	31.1	36.8	67.9	38-1	6.3	10.5	16.8
2	92.0	58.4	150.4	2	80.0	55.4	135.4
3	5.9	10.5	16.4	3	8.2	14.3	22.5
4	5.2	6.5	11.7	4	6.4	8.4	14.8
28-1	5.8	11.5	17.3	39-1	15.5	10.2	25.7
2	5.2	6.7	11.9	2	11.2	16.6	27.8
3	5.0	6.1	11.1	3	5.8	9.7	15.5
4	9.1	4.6	13.7	4	5.8	6.7	12.5
29-1	6.1	9.5	16.6	40-1	3.1	7.1	10.2
2	4.3	8.7	13.0	2	5.2	19.0	24.2
3	5.5	6.3	11.8	3	6.0	12.0	18.0
4	5.5	5.4	10.9	4	6.0	7.9	13.9
30-1	4.5	8.1	12.6	41-1	4.3	7.4	11.7
2	6.3	8.3	14.6	2	4.2	8.8	13.0
3	6.0	6.4	12.4	3	4.7	8.2	12.9
4	4.8	6.0	12.8	4	5.2	8.2	13.4
31-1	6.4	6.1	12.5	42-1	7.0	7.0	14.0
2	5.0	6.0	11.0	2	4.5	8.2	12.7
3	7.5	7.4	14.9	3	6.3	6.5	12.8
4	8.0	6.2	14.2	4	7.5	6.8	14.3

Table IV (Continued)

Sample #	NH_4*	NO_3*	Total	Sample #	NH_4*	NO_3*	Total
43-1	3.5	7.8	11.1	52-1	8.3	31.0	39.3
2	3.3	9.2	12.5	2	6.0	20.2	26.2
3	5.1	6.5	11.6	3	6.0	9.0	15.0
4	6.8	5.5	12.3	4	6.9	5.0	11.9
44-1	5.2	8.5	13.7	53-1	5.9	20.5	26.4
2	5.7	10.2	15.9	2	4.1	14.0	18.1
3	5.5	6.0	11.5	3	5.7	5.6	11.1
4	6.9	5.6	12.5	4	6.5	4.6	11.1
45-1	4.0	8.6	12.6	54-1	4.5	14.9	19.4
2	4.9	7.1	12.0	2	7.0	9.8	16.8
3	5.2	6.4	11.6	3	5.6	5.5	11.1
4	7.0	6.2	13.2	4	6.8	5.3	12.1
46-1	4.8	13.4	18.2	55-1	8.5	9.1	17.6
2	4.1	11.7	15.8	2	5.1	7.4	12.5
3	5.3	7.5	12.8	3	6.4	5.5	11.9
4	5.5	6.8	12.3	4	5.2	4.8	19.1
47-1	23.5	32.1	55.6	56-1	4.9	10.9	15.8
2	6.0	17.9	23.9	2	4.6	7.5	12.1
3	6.3	8.7	15.0	3	5.2	6.0	11.2
4	6.0	7.1	13.1	4	5.0	4.3	9.3
48-1	88.0	65.6	153.6	57-1	4.4	9.8	14.2
2	33.4	35.8	69.2	2	3.6	7.7	11.3
3	6.5	8.4	14.9	3	4.1	5.9	10.0
4	5.2	6.7	11.9	4	5.3	6.1	11.4
49-1	107.6	47.8	155.4	58-1	8.0	9.0	17.0
2	17.5	28.3	45.8	2	4.3	8.1	12.4
3	5.5	9.3	14.8	3	5.2	5.9	11.1
4	5.7	6.8	12.5	4	5.5	5.3	10.8
50-1	104.0	67.4	171.4	59-1	6.2	10.7	16.9
2	72.8	50.0	122.8	2	4.6	5.8	10.4
3	6.0	7.3	13.3	3	4.6	5.1	9.7
4	6.1	6.2	12.3	4	7.0	5.5	12.5
51-1	48.8	66.0	114.8	60-1	15.6	16.7	32.3
2	7.4	20.2	27.6	2	5.6	12.1	17.8
3	5.3	6.7	12.0	3	4.8	6.4	11.2
4	6.3	6.0	12.3	4	5.4	5.4	10.8

*All values are reported in ppm.

EVALUATIONS OF AMMONIA APPLICATION TECHNIQUES

by

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ABSTRACT

Studies were conducted in 1977 and 1978 to evaluate the effectiveness of Cold-Flo ammonia application techniques. This technique involves allowing ammonia to serve as its own refrigerant by releasing the ammonia into a chamber with an opening for vapor and a drain for liquid ammonia. Release of the pressure allows the ammonia to boil ($-33^{o}C$). Approximately 15% of the ammonia is converted into gas and the remainder is delivered to the soil as a liquid with very little pressure in the line. This reduces the seal needed to trap the NH_3 compared to pressurized NH_3. However, both liquid and vapor must be injected into the soil for good ammonia retention.

Different methods of NH_3 application were compared for their effect on yield and nutrient uptake by corn, grain sorghum and wheat. The methods examined in the wheat studies included N solution (UAN) broadcast preplant, UAN dribble preplant, UAN shanked preplant, disc with Cold-Flo ammonia preplant, conventional shank ammonia preplant, UAN broadcast topdress and UAN dribble topdress. Other methods compared on corn and grain sorghum included field cultivator with ammonia, field cultivator with Cold-Flo ammonia, all as preplant treatments. Nitrogen rates ranged from 34-101 kg/ha on wheat, 84-253 kg/ha on corn, and 45-135 kg/ha on grain sorghum.

There were no significant, consistent differences between methods of ammonia application in terms of crop yields or tissue composition. Protein content of wheat was not significantly effected by methods of ammonia application, but in 1977 topdress N application increased protein over preplant N.

Soil profile sampling was carried out to evaluate distribution patterns of ammonia from the different methods of application. Comparisons of the size of the retention zones from conventional ammonia and Cold-Flo ammonia applications were also evaluated and found to be comparable.

Ammonia distribution varied between points of release with each implement. The chisel plow with Cold-Flo ammonia had the most variation between shanks at the point sampled. There were essentially no differences in the size of the retention zones of conventional ammonia when compared to Cold-Flo ammonia.